1931

University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 358 JULY, 1931

Comparison of Apparently Healthy Strains and Tuber Lines of Potatoes

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BULLETIN 358

COMPARISONS OF APPARENTLY HEALTHY STRAINS AND TUBER LINES OF POTATOES

Donald Folsom, F. V. Owen,[1] and Hugh B. Smith[2]

INTRODUCTION

Previous to the present studies, which were begun in 1923, it was thought by many potato growers and scientists that the commercial strains of any potato variety were more or less different from one another. A commercial strain often could be traced back to some place or some grower from which or from whom its current name had been derived. Commercial strains, it was thought, might give rise to other commercial strains or substrains through selection, renaming, or apparent change. Each commercial strain was considered further as consisting of biological or natural strains, presumably originating from tubers, eyes, or hills that had developed differences.

By 1923 it had become evident that, at least in some varieties, differences between strains in apparent vigor and yielding power might be due to differences in degeneration-disease content. (Degeneration diseases, also called virus diseases or viroses, include leafroll, yellowtop, spindle tuber, curly dwarf, streak, and several kinds of mosaic. See *34*, p. 22-23; *39*, p. 59, 91-92; *101; 104*, Table VIII.)[3] As long as these diseases were not recognized as such, due to being spread by insects and often not showing until after the dormant period in the tubers had been passed, it would seem obvious that new biological strains could and did develop spontaneously in a field of similar plants some of which produced abnormal progeny really because they were attacked by disease. It would also seem obvious that substrains could become different by being grown in different fields wherein degeneration diseases increased at different rates. Some of these diseases, in

[1]Formerly Associate Biologist.
[2]Formerly Assistant Biologist.
[3]Numbers in italics refer to Literature Cited at the end of this bulletin.

certain varieties, are practically unrecognizable now even when known to be present, often requiring transference to other varieties for convincing demonstration of their presence. (This is discussed more fully on p. 75). This new knowledge pertaining to degeneration diseases made it seem reasonable, by 1923, to think that many, and perhaps all, previously reported differences between commercial strains and between biological strains were due to differences in disease content.

In 1923, in Maine, efforts were being made by some growers to introduce healthy commercial strains from other regions. (In this bulletin, the term "healthy strains" means "apparently healthy strains", or strains free of recognizable seed-borne diseases such as blackleg, wilt, scab, rhizoctonia disease, late blight, mosaic, leafroll, and spindle tuber. In fact, however, our tests show that all commercial potatoes are carrying at least one masked mosaic.) The question arose whether or not some healthy strains might be superior to others. It was thought that a careful comparison of some healthy strains might give interesting and useful results. One result hoped for was definite figures showing how large the differences between healthy strains might be, if indeed there were any such differences. Another result hoped for was a better understanding of the relative effect of heredity, environment, and diseases in causing differences between strains. It was also expected that known methods of making comparisons between healthy strains would be improved, and new methods would be developed, so that healthy strains could be compared more easily and more reliably than before.

In addition to comparing healthy strains in regard to vigor of vine growth and in regard to yielding power, it was planned to compare them in regard to tuber type. (In this bulletin "tuber type" refers to the shape of the tubers, as distinguished from quality, texture, condition, defectiveness, size, or weight). Here again degeneration diseases, such as spindle tuber and curly dwarf, were known to furnish reasonable explanations for strain differences reported previously (*33; 104*, p. 55-60; *105*). It was hoped that these pathological causes of modification of shape could be eliminated in our study of type.

In addition to comparing commercial strains, it was planned to compare tuber lines within a commercial strain. (In this bulletin a "tuber line" is a seed stock, perpetuated from year to year,

that is known to have originated from a single tuber. Such a tuber line is also known as one form of a clone.) One purpose of tuber-line comparisons was to test to some extent the opinion that a commercial strain generally comprises various biological strains. Another purpose was to test the possibility of a grower selecting superior tuber lines within a commercial strain.

It may be noted that Aroostook County seemed to be a desirable place for making comparisons of strains and tuber lines. In this county the total yield of potatoes was great enough to give economic importance to any proof that one strain or another was superior. With diseases and other conditions varying from region to region, tests would have to be made here to be applicable here. (See *82*, p. 13.)

Finally, Aroostook County seemed to be a favorable place for such comparisons. Here the general yield rate usually is high,[4] probably because "the potato, more readily than other domestic plants, responds, and responds liberally, to good culture and generous manuring" (*94*, p. 64). Therefore, differences might be more easily disclosed. Also, evidence had accumulated which showed that degeneration diseases were both detected and kept under control more easily in Aroostook County than in many other regions (*37*; *38*; *39*).

GENERAL METHODS

Before describing the detailed procedure and the results of our comparisons, it seems desirable to discuss the general phases of the methods of making such comparisons, especially with reference to the selection of characteristics to be compared, the selection of the variety, the selection of strains to be compared, disease control, yield determination, the measurement of tuber shape, and sorting by tuber weight.

SELECTION OF CHARACTERISTICS FOR COMPARISON

Yield and tuber type were referred to in the preceding paragraphs as appearing most interesting and important for study in

[4]Usually the highest in the United States (*15*, Table 2; *73*, p. 10) although, of course, lower than in some European countries (*15*, Table 13; *73*, p. 10) and much lower than the present world's record of 1145 bushels an acre *(89)*.

strain comparisons. It should be pointed out here that in addition other characteristics might be studied. Such are those of germination, flowers, foliage, habit of growth, stem color, stolon formation, tuber number, tuber variability, tuber size, maturity, and disease resistance. Time was not available for careful observation of more than a few of these.

Selection of Variety and Strains

Most of the strains compared in this study were of the Green Mountain variety. By this is not meant that they were known to have originated in one seedling, but rather that they had common characteristics causing them to be designated by the trade, by seed certification inspectors, and by scientific observers, as Green Mountains. The known origin of the individual strains will be given later.

Green Mountains are the leading table-stock variety in Maine in total yield and total crop value, and rank along with Irish Cobblers and Spaulding Rose in export-seed value. The variety is therefore of great economic importance. As a result, much attention is given by economic interests to the clams of superiority made for one or another of the various commercial strains that are available, or for one or another region as a source of seed stock.

This variety has become and has remained one of the most important in North America. Stuart lists it with 5 of the Rural and Burbank types and 9 other varieties among the 15 in a list "believed to include all the varieties of strictly commercial importance" (*117*, p. 46). Stuart also says that "the members of the Green Mountain group may be said to divide honors with those of the Rural in their commercial importance as a late or main-crop variety. They seem to be peculiarly well adapted to northern latitudes, where the rainfall is abundant and the temperature is not excessively high" (*117*, p. 461).

The Green Mountain variety is also of scientific interest because it probably is the variety of potatoes that is best understood in North America as to the effects of the degeneration diseases. It is the opinion of Salaman that among "the factors affecting the yield of a variety which are inherent in the seed tuber......the existence or otherwise in the tuber of the causative agent or agents

of virus diseases outweighs in importance all the other factors conveyed by the tuber individually and collectively." Further, in Green Mountains at least two and possibly three degeneration diseases are known that affect the shape or type of the tuber (*34*, p. 23; *104*, Table VIII). Better knowledge of the degeneration diseases in a variety should lead to greater reliability in strain and tuber-line comparisons within that variety.

Whatever the variety to which the strains of a comparison belong, there are important factors to be considered in the selection of the strains to be compared. The matter may be viewed from the standpoint of the annual importer of strains. Various healthy strains brought together from different sources, even when known to be of a formerly single origin, theoretically can be expected to differ from each other in the first season's comparison, due to persisting effects of differences in disease content,[5] in maturity, in storage, in field conditions of their production, and in selection of the tubers secured for seed. Here the first season's results are all-important. On the other hand, the matter may also be viewed from the standpoint of one wishing to grow the same strain locally for several seasons. In a series of strains a particular strain might show certain characteristics the first season after being introduced but thereafter it might be like the rest of the series. If such a change occurred it could be attributed either to the effects of the previous environment upon the tubers used for seed, or to the acquirement of masked degeneration diseases. In this study some attention was paid to both viewpoints.

Disease Control

For the best results, all seed stocks should be free from recognizable degeneration diseases. If there is any apparent difference as to certain fungous or bacterial diseases, seed treatment should be employed in such a way that it is effective and yet not a cause of further differences through sprout injury of some seed stocks. Degeneration diseases should be rogued effectively, especially if the series of strains is to be compared during a period of

[5]Referring to certain masked degeneration diseases, which have been found, by inoculating the sap into other kinds of plants, to be present in all Green Mountains. Excluding the degeneration diseases listed on p. 1.

several years. Roguing is most effective if done by tuber units. (A tuber unit is a group of adjacent hills planted from one tuber.) Differences in disease content of the soil should be avoided.

YIELD DETERMINATIONS

It is interesting to note that Kiesselbach in 1918 showed that most of 471 reports of field tests failed to describe the methods fully (*56*, p. 90). It may be emphasized here that little was available about field technique with potatoes when our comparisons were begun in 1922. In our work the methods of determining yield rates have varied somewhat from one season to another. Hence it seems desirable to describe the methods, or any changes in previous methods, for each season when the results are described. A discussion of methods used elsewhere will be given later.

MEASUREMENT OF TUBER SHAPE

Ranking in importance with the question of yield is the question of tuber type, by which we mean tuber shape. As pointed out by Salaman, "in a 'long' tuber, a ventral side can generally be distinguished as being the one freer from eyes; it is usually somewhat flat or even concave, whilst the opposite or dorsal side is furnished with more eyes and is convex. If the tuber be placed on a flat surface ventral side down, the lateral contour can then be readily appreciated" (*94*, p. 189).[6]

Length is usually judged in its relation to width as seen facing the dorsal side, and so can best be interpreted, when measured quantitatively, in terms of L/W (length divided by width, or ratio of the one to the other) with W considered as 1.0 or as 100. (Fig. 1). Thickness is usually judged in its relation to width as seen facing one end or the other, and can best be interpreted, when measured, in terms of T/W (thickness divided by width, or ratio of the one to the other) with W again considered

[6]This was also the position, in the soil, of over 99 per cent of the tubers examined in 200 feet of row of Green Mountains in Maine. Six tubers in the 200 feet of row, however, were found exactly reversed to the normal position.

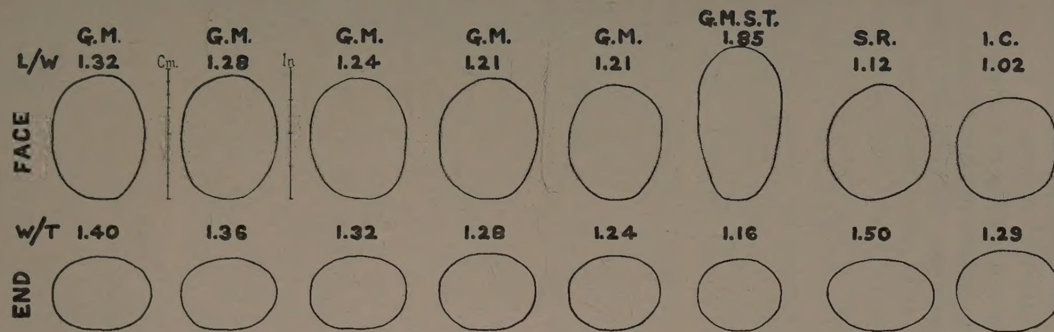

FIG. 1. Ideal profiles of tubers, face and end views, with various L/W and W/T ratios, L designating length, W width, and T thickness. Green Mountain (G.M.), Spaulding Rose (S.R.), Irish Cobbler (I.C.), and spindle-tuber (S.T.). See Fig. 16 for device for measuring dimensions, and Figs. 6 and 7 for profiles of actual tubers.

as unity or as 100. Measurements in these studies were made as in previous studies of spindle tuber (*104*, p. 56) using a wooden caliper (Fig. 16) of special construction devised by Dr. F. A. Krantz of the Minnesota Agricultural Experiment Station. Length pertains to a line perpendicular to the W and T lines, or a general stem- to bud-end axis, rather than to the longest possible dimension or axis. The L/W and W/T ratios were calculated for the individual tubers in order to get a mean ratio with P. E.

In most studies of tuber shape with the measurements expressed in such ratios, it apparently has not been realized that the L/W ratio may vary with the weight of the tuber. In our work the basis of type study has been measurements of 8-ounce tubers. This weight of tuber, actually 8.0 ± 0.5 ounces as sorted and measured, is frequent enough for statistical work, and at its normal dimensions produces fairly good shape as exhibitors and exhibition judges rank shape. Usually 50 tubers per sample were measured. These were taken at random from the 8-ounce class obtained by the sorting described in the next section of this bulletin.

Although the measurement of three dimensions of 8-ounce tubers has proved helpful in getting a standard numerical expression of tuber type, such an expression does not go far enough. With the same dimensional ratios, shape can vary considerably. Records of different shapes of tubers with the same dimensions, can be made using such expressions as oblong, elliptical, oval, with pointed stem-end, with pointed eye-end, wasp-waisted, dumbbell shaped, etc. Profiles of tubers, as faced, can be made by outlining their shadows. (Figs. 1, 6, and 7.) Plaster-of-Paris models can be made of tubers with different shapes, designated by number or letter, and used in the classification of tubers by types. (Fig. 17.)

In Green Mountains, tubers were measured which were of regular shape and of appearance approved by Dr. Chas. F. Clark of the U. S. Dept. of Agriculture, a specialist on potato breeding and varietal characteristics. It was thus found that in this variety an "ideal" 8-ounce tuber had a length of 9 to 10 cm. (about 3.5 to 4 inches), a width of 7 cm. (about 2.75 inches), and a thickness of 5 to 5.5 cm. (slightly over 2 inches). Corresponding dimension-ratios are 1.3 to 1.4 for L/W and the same for W/T. That is, the length should be about one-third greater than the

width and the width about one-third greater than the thickness. (See Fig. 1, G. M. with L/W 1.32 and G. M. with W/T 1.36; *114*, Plate XIV, Fig. 2; Fig. 17, tuber 4—although tuber 3 was considered "standard" and represented by far the most tubers in the comparison of Green Mountain strains in 1927, Table 6; Table 10.)

Tuber Sorting by Weight

It has just been pointed out that differences in the weight of tubers cause corresponding differences in shape. In general, the heavier the tuber in a given lot, the greater is the L/W (length: width) ratio.

Aside from this correlation between weight and shape, the weight or size of tubers often has economic importance. The extremes are barred by trade preference and grading rules. Even similarity of size may have a value through affecting the appearance of a bulk stock. Therefore classification by weight was extended to all the tubers in presumably representative samples of various strains. This was done by weighing the individual tubers on a spring balance and tossing them into padded crates labeled according to the tuber weight. More rapid sorting could have been done if a machine sizer (*3*, p. 11) had been available. This in turn would have permitted the sorting of more samples from each strain, with greater reliability of results.

The weight classification was made by ounces; for example, a tuber weighing between 2.5 and 3.5 ounces was put into the 3-ounce class and crate. At the end of the sorting of a sample each ounce class could be weighed in mass or the tubers counted in each class. As seen in Fig. 4, the ounce classes containing most of the tubers by number may be lower in the scale than the ounce classes containing most of the tubers by weight. This is due to several classes having so nearly the same number of tubers that the differences in average weight of tuber shifts the peak of the distribution perceptibly. It is the percentage of tubers by number in a given class that interests the statistician, while it is the percentage of tubers by aggregate weight, as sold on the market, that interests the grower.

COMPARISON OF GREEN MOUNTAIN COMMERCIAL STRAINS, FIRST SERIES

ORIGINS OF STRAINS

The Green Mountain variety was introduced by O. Alexander, according to Salaman (*94*, p. 10). Stuart states of it: "Originated by O. H. Alexander, Charlotte, Vt., in 1878; claimed to be a seedling from a cross between Dunmore and Excelsior. Introduced by J. A. Everitt & Co. in 1885." (*114*, p. 34.)

According to an authoritative definition of synonymy, that of the Synonym Committee of the National Institute of Agricultural Botany of England, a genuine newborn seedling may be similar enough to an existent variety to be required to be designated by the same name (*94*, p. 137-138). According to this view, it would be at least theoretically possible to assemble several strains all similar enough to pass as Green Mountains in spite of all being of separate seedling origin. This has been done with other varieties, according to East (*26*, p. 387-388; *27*, p. 130) and Chittenden (*18*, p. 42, 45). The strains in such a collection, while apparently uniform, might still show differences in yield or tuber type if compared carefully. It is not known how many of the stocks now passing as Green Mountains actually are descendent from the stock originated by Alexander and how many are descendent from other seedling stocks. A variety called "Green Mountain, Jr." is listed by Stuart as being an inbred Green Mountain seedling, but apparently is regarded by him as being similar (*114*, p. 34) and is regarded by the British Synonym Committee as synonymous with "Green Mountain" (*94*, p. 153). We ourselves have produced inbred Green Mountain seedlings that seemed identical with the parent. Krantz thinks, however, that introduced synonymous seedlings "have been relatively few in number" (*67*, p. 8).

For this series, preparations were made in 1922 and certain tuber characteristics were measured. Then seven strains were grown together in 1923. An eighth strain was secured in the spring of 1924. The known origins of these strains are as follows:

Ball strain. Grown on Aroostook Farm[7] in 1920, having been secured from Mr. Ball of Vermont, and presumably having been grown by him in Vermont in 1919. In 1920, disease-free, but grown only 90 feet distant from diseased Irish Cobblers. In 1921, grown on Aroostook Farm in an isolated plot, planted in commercial style, with 10 per cent of the plants rogued during the summer for diseases (mosaic and leafroll), and with some spindle tuber present. In 1922, again grown on Aroostook Farm in an isolated plot, this season planted by tuber units, with 20 per cent removed as diseased (mosaic, spindle tuber). Field-run sample used for 1922 tuber comparisons.

Corinna strain. In the spring of 1923, secured from near Corinna, in south central Maine, where presumably it was grown in 1922 by a seed firm (see *123*, p. 19) reporting this strain to be "Pride of Vermont" stock once grown by Mr. Nye in Vermont. This probably is the same as that called "the variety Pride of Vermont" by Stewart (*111*, p. 347). This is considered in Vermont to be probably a distinct variety from Green Mountains, but "there is so little apparent difference between these varieties however, that they are indistinguishable from a practical standpoint" (*8*, p. 71). This authority also states that Mr. Nye probably secured it near Rochester, Vt., from stock tracing back to a Boston seed house. This stock as received in 1923 probably had been graded or sorted at Corinna from the 1922 crop.

H. & C. strain. Small sample taken in 1922 in an Aroostook County field containing a trace of disease and said by the owner to have been planted with the Corinna strain, using seed produced in 1921 near Corinna.

Cunningham strain. Obtained in the spring of 1923 from an Aroostook County grower in the form of oversized and partly decayed cull tubers of stock said by the owner to have been received from New Brunswick, Canada, near Chaleur Bay, and presumably grown there in 1922.

B. & A. strain. Grown in 1921 on farm adjacent to Aroostook Farm, with less than 1 per cent of the plants degeneration-diseased, from stock said by the owner to have been received

[7]Experimental farm of the Maine Agricultural Experiment Station, near Presque Isle, Maine.

from Prince Edward Island, Canada, as of the McFadyen strain. Learned by Dr. W. J. Morse of the Maine Agricultural Experiment Station, when visiting in that region in 1920, that McFadyen in 1920 had a strain grown locally for 30 years, and obtained originally from Syracuse, N. Y. In 1922, grown on Aroostook Farm in the same seed plot with the Ball strain, and planted by tuber units, with 8 per cent removed as diseased. Field-run sample used for 1922 tuber comparisons.

Rich strain. Secured in the fall of 1921 as the exhibit given the first prize on type, etc., in the annual autumnal Maine agricultural seed show. (Figs. 2 and 3.) Said by owner to have

FIG. 2. Origin of Rich strain in these comparisons. Note scale of inches and centimeters. See Fig. 3 for same tubers separated.

been selected from stock grown in Charleston, in south central Maine near Corinna, in 1921, from stock received from Prince Edward Island, Canada, as of the McPherson strain. In 1922, grown on Aroostook Farm in the same seed plot with the Ball strain, planted by tuber units, with none found diseased. Field-run sample used for 1922 tuber comparisons.

Fig. 3. Origin of Rich strain in these comparisons. Note scale of inches. See Fig. 2 for same tubers in a pile.

P. E. I. strain. Secured in the spring of 1922 as certified seed from Prince Edward Island, and as of the Dr. Johnston strain, stored in the province over winter. Apparently but not necessarily selected, and probably graded.

Reeves strain. Secured in the spring of 1923 from the firm supplying the Corinna strain, and represented as having been grown in New York in 1922. Possibly sorted or graded at place of origin.

Therefore it was believed that in this series comparisons were made of two strains from Vermont, one from New Brunswick, three from Prince Edward Island, and one from New York. An eighth strain was thought to be actually a part of one of the Vermont strains.

COMPARISON OF ORIGINAL STOCKS GROWN IN 1922

TUBER WEIGHTS

As indicated in the preceding section, the seven strains grown together in 1923 were secured in the form of samples from stocks grown in several different places in 1922. The H. & C. sample lot was too small to be sorted and the Cunningham lot was too defective. Of each of the other five strains about 300 pounds or 800 tubers were sorted in the spring of 1923, as representing the crop of 1922. Two of the five, the Corinna and P. E. I. lots, may have been sorted before receipt, so that they probably do not represent the 1922 field-run stocks from which they came.

The Ball, B. & A., and Rich lots were as field-run in 1922 as grown on Aroostook Farm in the same plot, and can be compared most advantageously. The mean tuber weight of the Rich and B. & A. strains was about the same while that for the Ball strain was significantly lower. In bar charts, like those shown for a later season in Fig. 4, the B. & A. strain tends to have the largest tubers, both by number and aggregate weight of tubers per ounce-class. The Ball strain has the smallest by either standard.

TUBER DIMENSIONS

The five strains referred to as being sorted in the spring of 1923, showed no significant differences in any dimension of the 8-ounce tubers or in the L/W (length:width) ratio, but the W/T (width:thickness) ratio was significantly higher for the Corinna strain than for the Ball strain. Considering the different origins of various strains, the general absence of significant differences is interesting.

In both the Ball and the Corinna strains, the L/W ratio is significantly greater for the 8-ounce tubers than for 4-ounce tubers, while the W/T ratio is significantly greater for the 8-ounce tubers in the Corinna strain but about the same in the Ball strain. This shows that tuber weight may affect tuber type.

Comparisons in 1923

GENERAL PROCEDURE

In the spring the different seed lots were sorted as to tuber weight and measured as to the dimensions of 8-ounce and 4-ounce tubers, as described previously. Routine cold-formaldehyde disinfection was applied to the Corinna lot (1- to 8-ounce tubers only) on May 15, and to the P. E. I. lot before May 15. The latter had produced some sprouts when received and the bruised sprouts were badly blackened by the disinfectant. The Ball, H. & C., B. & A., and Rich lots were apparently free from Rhizoctonia and were not treated. No treatment was given to the Cunningham lot, and this lot was planted differently from the others as to size of seed piece and spacing of hills.

All the rows were furrowed out at one time and at the same time were fertilized at the rate of about 1800 lbs. to an acre with 5-8-7 goods. Planting in the open fertilized furrow was done by hand. One weight-class was planted at a time, and each tuber was cut into as many seed pieces as there were ounces in the tuber weight. The seed pieces, thus averaging an ounce each, were planted at 12-inch intervals, measured with a marked rod. Other data are given in Table 1.

Diseased plants and admixtures were rogued out for the first time on July 26, 27, and 28, and later on August 2 and August 13. This roguing left apparently healthy hills, some of which were actually infected before the time of roguing according to further information obtained in 1924. The apparently healthy hills left after the roguing, appeared to be all of the Green Mountain variety. On July 27th the plants in plot 12 were not as far advanced in some places as those in plot 10. On August 2, plants in plots 18 to 26 seemed somewhat smaller than in the preceding plots. Cultivator injury, blackleg, and Rhizoctonia were found occasionally. The percentage of healthy hills is given in Table 1. Measurements of the distances between rows showed that there were about 14,000 hills in an acre.

TABLE 1

Green Mountain Strain Comparison in 1923

Strain	Plot[1]	No. of rows	Date of planting	Weights of seed tubers: In Plot	Weights of seed tubers: In t.w. row[2]	Sprouts at planting	Healthy hills %	Yield per hill[3]	Yield per acre[3]: Bushels	Yield per acre[3]: Barrels
								Lbs.		
Ball	2	2	5/30 P.M.	6 to 12+	7–8	Small	81.0	1.81	422.3	153.6
	5	2	"	4 to 7	—			1.85	431.7	157.0
	8	2	5/31 A.M.	3 to 4	—			1.89	441.0	160.4
Corinna	1	1	5/30 P.M.	10 to 12+	—	Large enough for injury from handling	98.3	[4]	—	—
	3	2	"	8 to 11	—			2.01	469.0	170.5
	7	2	5/31 A.M.	7 & 8	8			1.91	445.7	162.1
	10	4	"	6 & 7	—			1.88	438.7	159.5
	13	4	5/31 P.M.	6	—			1.90	443.3	161.2
	16	4	6/1 P.M.	5	—			1.95	455.0	165.5
H. & C.	4	1	5/30 P.M.	5 to 11	5–11	—	100.0	1.99	464.3	168.8
Cunningham	14	2	5/31 P.M.	[5]	—	—	100.0	[5]	—	—
B. & A.	19	2	6/2 A.M.	8 to 14	—	Well sprouted	73.7	1.83	427.0	155.3
	22	2	6/2 P.M.	6 to 8	6–8			1.91	445.7	162.1
	25	2	"	5 & 6	—			1.96	457.3	166.3
Rich	20	2	6/2 P.M.	8 to 14	—	Well sprouted	80.1	2.04	476.0	173.1
	23	2	"	6 to 8	7			1.90	443.3	161.2
	26	2	"	4 & 5	—			1.92	448.0	162.9
P. E. I.	12	4	5/31	9 to 15	—	Small. Few eyes dead from seed treatment	99.8	1.89	441.0	160.4
	15	4	" P.M.	7 to 9	8			1.90	443.3	161.2
	18	4	6/1 P.M., 6/2 A.M.	6 to 8	—			1.84	429.3	156.1
	21	2	6/2 P.M.	6	—			1.88	438.7	159.5
	24	2	"	5 & 6	—			1.90	443.3	161.2

[1]Numbered in order of arrangement from east to west.
[2]In row dug and graded for tuber weight.
[3]Corrected for roguing and for growing next to rogued hills.
[4]Outside buffer row.
[5]Culls used for seed—oversize and partly decayed.

YIELDS OF HEALTHY HILLS NEXT TO ROGUED HILLS

After the frosts of September 14 and 20 had killed the vines, certain hills were dug and weighed separately in order to determine the average effect of roguing a hill next to a healthy hill. These hills were dug in plot 5 in the 5-ounce or 5-hill tuber units and in plot 8 in the 4-ounce or 4-hill tuber units. Each tuber unit had been planted from north to south dropping the stem-end pieces first and the eye-end pieces last. Therefore for each hill next to a rogued hill, two controls were dug, one being the adjoining hill in the same tuber unit and the other being the correspondingly placed hill in the next tuber unit. The average yield was 44.8 ounces for the 44 hills thus dug, 34.7 ounces for the first control, and 33.6 ounces for the second control. Therefore 10 ounces were subtracted from the yield of each healthy hill next to a rogued hill, in computing yields.

TOTAL YIELDS OF PLOTS

The unrogued hills dug in the preceding study were restored to the places where grown and included with the rest when dug by machine. The net weight of the yield from each plot was determined on a large platform scales[8] by difference between the gross weight in barrels and the weight of the barrels. From the number of hills in each plot, the number of hills per acre, and the yield (corrected for roguing and for the effect of some hills growing next to rogued hills) of each plot, the yield rates in pounds per hill and in barrels and bushels per acre were calculated. They are given in Table 1.

The mean yields of the various strain series of plots ranged from 1.85 to 1.97 pounds per hill. (1.90 lbs. per hill would be at the rate of 443 bushels or 161 barrels per acre). This is not a great range. There was no significant difference between the mean yields except possibly in one of three comparisons between the Ball and Corinna strain, the latter outyielding the other by 0.08 lbs. per hill (about 19 bushels or 7 barrels per acre) with the P. E. of the difference 0.02 lbs.

[8]Sensitive to at least ±2.5 lbs. Weighings recorded in multiples of 5 pounds.

TUBER WEIGHTS

About two barrels (5½ bushels, or 330 pounds) of each of the seven lots were sorted into ounce classes in the fall. The Cunningham lot was not planted like the rest, it must be remembered. The two barrels used from each lot were grown on Caribou loam in one row and represented a large part of the row. Table 1, column 6, gives the size of seed tubers used for planting the rows that were dug for tuber-weight sorting. It was about the same (6 to 8 ounces) for all but the Cunningham and H. & C. strains.

According to the statistical comparisons in regard to tuber weight, the Ball strain was lower than all others, and the B. & A. strain higher than all others, each with significance except in one comparison between strains. This difference is the same as that found in 1922. The P. E. I. strain, highest in 1922 due to its being represented by selected seed tubers, in 1923 was next to the lowest and was not significantly different from the lowest.

According to a bar chart, on the basis of tuber number the tuber-weight curve has its peak in heavier tuber classes in the B. & A. strain and in lighter classes in the Ball strain, with respect to the other strains, thus confirming the comparisons of the means. On the basis of weight the Cunningham strain has a strikingly large proportion of overweight tubers (of 16 or more ounces in weight). Otherwise the curves of distributions are similar, the peak falling in the region of 6- to 9-ounce classes.

The data here apparently confirm the contention of some persons, that large seed tubers will give large-sized tubers in the crop, as far as the Cunningham strain is concerned, but not with respect to the P. E. I. strain. The method of planting the Cunningham strain was decidedly different, this lot being the only one planted with skips between the tuber units. From skips between tuber units a decrease of uniformity can well be expected in size of hills and consequently in size of tubers. The overweight and partly rotted nature of the seed tubers caused the use of one eye to the hill to be more frequent than for the other strains. With more single-eye seed pieces, more hills can be expected with fewer stalks, fewer tubers, and larger tubers.

TUBER DIMENSIONS

In very few comparisons was a strain significantly different from any other with respect to any dimension, in either 8-ounce or 4-ounce tubers.

The mean length of 8-ounce tubers was greatest in the Ball strain, smallest in the Cunningham, and next to the smallest in the B. & A. The mean width of these tubers was greatest in the Cunningham strain, next greatest in the B. & A., and smallest in the Ball. None of these three strains was distinctive as to thickness. Therefore, in the L/W ratio the Ball strain was first with the B. & A. and Cunningham strains last, and in the W/T ratio the Cunningham strain was first with the B. & A. strain near the first and the Ball strain last.

Comparing 8-ounce and 4-ounce tuber ratios in the same strain, again the L/W ratio is significantly greater for the 8-ounce tubers in both strains and again the W/T ratio showed a greater increase for the 8-ounce tubers in the Corinna strain than in the Ball strain.

Comparisons in 1924

GENERAL PROCEDURE

The seven stocks of the 1923 comparison were stored in the same cellar and compared in 1924. The Reeves strain was introduced with the seed from New York. All strains were planted by tuber units by hand in an isolated seed plot which was rogued. From this plot came the lots that were sorted into tuber-weight classes. For this sorting, about two barrels or five bushels (about 330 pounds and about 700 to 800 tubers) were taken field-run along a row in Caribou loam. One or two of these weight classes were then used for dimension study. The strains were also planted by machine in replicated nonisolated and unrogued plots for yield comparison, the plots being two rows wide and 250 feet long. The seed was not treated. Other general data are given in Table 2.

TOTAL YIELDS OF PLOTS

The yield rates of the machine-planted plots, given in Table 2, were compared statistically. This gave significance to differ-

TABLE 2

Green Mountain Strain Comparison in 1924

Strain	Field	No. of plot[1]	Date of planting[2]	Weight of seed tubers[3]	Size of plants[4]	Healthy hills %[5]	Yield per acre Bushels	Yield per acre Barrels
Ball	Seed	3	6/3 A.M.	6 ounces	4	55[6]	—	—
	Yield	3	—	—	—	93	396	144
	"	7	—	—	—	91	411	149
	"	11	—	—	—	92	393	143
Corinna	Seed	63	6/6 A.M.	8 ounces	1	95	—	—
	"	64[7]	"	7 "	1	86	—	—
	Yield	1	—	—	—	97	429	156
	"	5	—	—	—	98	406	148
	"	9	—	—	—	96	409	149
H. & C.	Seed	23	6/4 P.M.	6 ounces	1	98	—	—
	Yield	2	—	—	—	99	446	162
	"	6	—	—	—	98	431	157
	"	10	—	—	—	96	411	149
Cunningham	Seed	11	6/3 P.M.	6 ounces	3	93	—	—
	Yield	15	—	—	—	97	381	138
	"	19	—	—	—	97	386	140
	"	23	—	—	—	96	368	134
B. & A.	Seed	7	6/3 P.M.	6 ounces	4	98	—	—
	Yield	14	—	—	—	95	396	144
	"	18	—	—	—	96	398	145
	"	22	—	—	—	96	383	139
Rich	Seed	15	6/4 A.M.	6 ounces	2	88	—	—
	Yield	13	—	—	—	97	393	143
	"	17	—	—	—	93	386	140
	"	21	—	—	—	96	381	138
P. E. I.	Seed	19	6/4 A.M.	6 ounces	2	95	—	—
	Yield	4	—	—	—	97	459	167
	"	8	—	—	—	99	398	145
	"	12	—	—	—	99	410	149
	"	16	—	—	—	98	393	143
	"	20	—	—	—	96	388	141
	"	24[8]	—	—	—	97	391	142
	"	25	—	—	—	97	378	138
	"	26[8]	—	—	—	?	398	145
	"	27	—	—	—	?	378	138
Reeves	Seed	35	6/5 A.M.	8 ounces	1	100	—	—
	Yield	28	—	—	—		393	143

[1]In seed field, single-row plots were numbered from east to west; in yield field, two-row plots were numbered from north to south.
[2]Yield test all planted on same date.
[3]Seed for yield test was cut to approximate and average 1 ounce per seed piece.
[4]On July 1, graded 1 to 5 in order of increasing size.
[5]In yield-test field, spindle tuber was not recorded and most recorded disease was mosaic.
[6]75 per cent for all rows of this strain in the seed plot.
[7]Tuber units separated by empty hill after each unit.
[8]Seed pieces partly rotted when planted.

ences in only 4 comparisons, where the H. & C. strain yielded more than the Ball strain, the B. & A. strain more than the Cunningham, and the P. E. I. more than the Cunningham (two comparisons). Table 2 shows that from north to south in this field there was a general decrease in yield. This is shown especially by the P. E. I. lots scattered across the field. This field variation can be allowed for, only by comparing all strains with the P. E. I. lots. Such comparison marks the H. & C., B. & A., and P. E. I strains as highest-yielding, the Corinna and Rich strains as medium-yielding, and the Ball and Cunningham strains as lowest-yielding. The Ball strain had about 12 per cent of the hills spindle-tuber in the seed plot and also, presumably, in the yield-test field, where this disease was not looked for because of the difficulty of detecting it in machine-planted stock.

TUBER WEIGHTS

The Corinna strain was planted in part (row E-64) with spaces between the tuber units. This lot was about the same as the part planted without spaces in the next row (E-63), in mean tuber weight. It was, however, different in the bar chart (Fig. 4), having the peak at a lower weight with respect to tuber numbers and in a higher weight class with respect to aggregate weight. That was because there was less uniformity of tuber weight with the skips between tuber units.

Contrary to the results of 1922 and 1923, when with respect to mean tuber weight the Ball strain was lowest and the B. & A. strain highest, in 1924 the Ball strain was slightly higher than the B. & A. No strain was significantly different from all others.

Fig. 4 shows that with respect to tuber number, the number of ounces in the peak class is greatest (8 oz.) for the Ball strain and least (4 to 7 oz.) for the B. & A. (excluding the Corinna lot with skips). This is the same relative position as for mean tuber weight. Still, with respect to weight of crop the number of ounces in the peak class is greatest for the B. & A. strain. Again as in 1923 the Cunningham strain has the greatest percentage of overweight tubers, especially on the basis of weight of crop, though this year the size of the seed planted was the same as for the other strains.

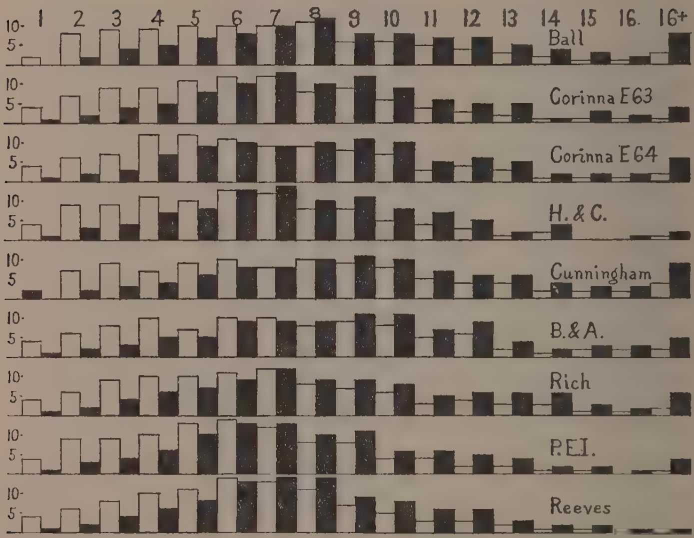

FIG. 4. Crop of 1924, Green Mountain strains compared as to tuber weight. Numbers at left indicate percentages. Numbers at top indicate weight of each tuber in ounces. The white bars by their height denote percentage of tubers, by number, of a certain tuber weight. The black bars denote percentage of crop, by weight, of a certain tuber weight. Compare with Figs. 8 and 9 for similar comparisons of varieties and of seasons.

TUBER DIMENSIONS

Inasmuch as in 1922 and 1923 the 4-ounce tubers differed much from the 8-ounce as to dimension ratios, only 8-ounce tubers were measured thereafter. In 1924 there were no significant differences between strains as to any mean dimension, except that the Corinna strain was significantly wider than most of the others. The Rich strain was longest, the Corinna strain shortest, the H. & C. strain narrowest, the Cunningham strain thickest, and the Rich strain thinnest. Actually the differences were not great (Fig. 5). In the L/W ratio the Rich strain stood ahead and the Corinna last. In the W/T ratio the Corinna strain stood ahead and the Cunningham last. The last relation is a reversal of the position held in 1923 when the Cunningham strain was first.

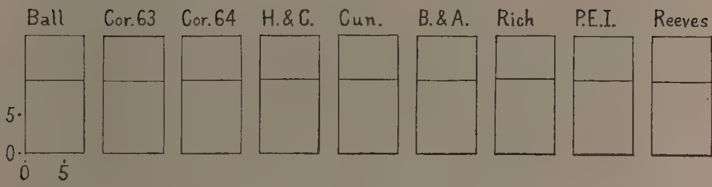

FIG. 5. Crop of 1924, Green Mountain strains compared as to tuber dimensions. The numbers indicate centimeters, 5 of which equal about two inches. In each small figure, the larger oblong at the bottom gives the dimensions (length and width) of the average tuber in face-view, while the smaller oblong at the top gives the dimensions (width and thickness) of the average tuber in end-view. See Fig. 16 for device for measuring dimensions, and Figs. 12, 13, and 14 for similar comparisons of varieties, diseased lots, and crops of different seasons.

COMPARISONS IN 1925

GENERAL PROCEDURE

As in 1924, the various strains were perpetuated in a tuber-unit rogued seed plot and 5-bushel samples from this plot were used for tuber-weight and tuber-dimension studies. For comparison as to yield, a field was marked out for 3-foot rows and each strain was planted by machine in the appropriate rows before another strain was planted. This reduced the time required for shifting seed in the planter, but increased the chance that a particular sack of fertilizer might be applied to one strain and so, if different, might modify the production of all the rows of that strain in the same way, making it different from the others through a systematic error. In this test most of the plots were single rows about 340 feet long, each containing about 310 hills. The yield rate was calculated in pounds per hill and in bushels and barrels per acre. General data are given in Table 3.

Another yield comparison was made in the seed plot, between series of tuber units planted by hand on May 25. Each tuber unit consisted of 4 hills grown from a 4-ounce tuber, with hills 12 inches apart in the unit and with 3 missing hills between each unit and the next one. In the first row 10 Ball strain units alternated with 10 Corinna strain units. In succeeding rows the Corinna strain, as control, alternated in the same way with the

B. & A., Cunningham, H. & C., P. E. I., Reeves, and Rich strains, respectively. At planting time it was noted that the Rich strain had more advanced sprouts than the others. At harvesting time the units that were healthy and unrogued were dug separately and the yields compared.

TABLE 3

Green Mountain Strain Comparison in 1925

Strain	Field	Nos. of rows[1]	Weight of seed tubers[2]	Healthy hills %[3]	Yield per hill[3]	Yield per acre[3] Bushels	Yield per acre[3] Barrels
					Lbs.		
Ball	Seed	2, 3, 4	7 to 8 ounces	80	—	—	—
	Yield	2, 10, 18, 26	—	81	1.64	365	132
Corinna	Seed	2, 3, 4	6 to 8 ounces[4]	95	—	—	—
	"	2, 3, 4	4 " [5]		—	—	—
	D. Y.[6]	—	—	98	1.61	350	127
	Yield	1, 5, 9, 13, 17, 21, 25, 29, 33	—	97	1.87	406	148
H–26[7]	Seed	7, 29	?	90	—	—	—
H. & C.	Seed	48	8 ounces	96	—	—	—
	Yield	8, 16, 24, 32	—	94	1.66	368	134
Cunningham	Seed	9, 39	8 ounces	96	—	—	—
	"	30	Over 16 oz.		—	—	—
	Yield	3, 11, 19, 27	—	96	1.77	396	144
B. & A.	Seed	35	7 to 8 ounces	93	—	—	—
	Yield	6, 14, 22, 30	—	93	1.65	365	133
Rich	Seed	42	8 ounces	93	—	—	—
	Yield	4, 12, 20, 28	—	96	1.65	369	134
P. E. I.	Seed	45	8 ounces	96	—	—	—
	Yield	7, 15, 23, 31	—	96	1.75	383	139
Reeves	Seed	51	8 ounces	94	—	—	—

[1]In seed field, rows numbered from east to west; in yield field, rows numbered from west to east.
[2]Seed pieces cut to approximate and average 1 oz. in weight in the yield test, and tubers quartered in the seed plot except for the Cunningham overweight, which were cut into two parts to each tuber and each part quartered and planted as for the smaller tubers.
[3]Averages for all plots of each strain.
[4]With one empty hill between each tuber unit and the next one.
[5]With 3 empty hills between each tuber unit and the next one.
[6]Disease-yield plot. See 39. Table 6, plots 20, 23, 26.
[7]A "high-yielding" tuber line of the Corinna strain.

YIELD RATES

According to Table 3, the Ball strain was not in the same class with the others as to freedom from recognizable diseases. In pounds per hill this strain yielded less than all others, though

not significantly so, in the field machine-planted test. The B. & A. strain was next lowest and the Corinna strain highest in this test with all differences but one significant; this was a reversal of the relative yields in 1924. Significant differences were slightly fewer using Student's method *(71; 72)*. In bushels per acre there was practically no change in rank from the status based on pounds per hill. Again the number of significant differences was less with Student's method than with Bessel's *(71A)*.[9]

In the comparison of strains made with the planting done by tuber units and with diseased units removed, differences between parts of the same strain (Corinna) in one row and another were as great as those between the Corinna and other strains in the same row. In this test the Ball, H. & C., and Rich strains form a higher-yielding group, the Corinna strain is medium-yielding, and the rest form a lower-yielding group, though only one comparison of 14 gives a significant difference. Thus in this tuber-unit test the result of the machine-planted test is not confirmed. This is due, with regard to the Ball strain, probably in part to the elimination of diseased hills, but in general is due to the great variation between tuber units and the inclusion of too few units to represent each strain.

TUBER WEIGHTS

The Corinna strain was sampled in several places. With 3 blank hills between each tuber unit and the next one, and with smaller tubers and seed pieces planted, the mean tuber weight was significantly greater than with only one skip between succeeding units. With the latter it was in turn significantly greater than with planting by means of a commercial machine in a different field, with no skips. With single skips the mean weight was about the same for the bulk Corinna stock as for a tuber-line selection begun in 1923 on the basis of high yield. These differences are found also in the bar charts for weight and number of tubers in ounce classes.

[9]Significance with Student's method requires odds of over 30 to 1, and with Bessel's method requires a ratio of over 3 to 1 between a difference and its probable error, the latter calculated as the square root of the sums of the squares of the probable errors of the means.

The Cunningham strain, which in 1923 and 1924 showed an excessive proportion of overweight tubers, was divided in 1925. One part consisting of overweight tubers yielded a tuber-weight mean that was significantly greater than that of another part consisting of 8-ounce tubers. This difference also appeared in the bar charts for ounce classes.

Among the samples representing the different strains there was one, the Reeves, that was significantly lower than all others in mean tuber weight. All the other strains, 7 in all, showed fewer significant differences among themselves. Further, these 7 showed a range from the highest (Ball) to the lowest (P. E. I.) that was only half of the difference between the two Cunningham lots, a third of the difference between the two Corinna lots planted in different fields, and a fourth of the difference between the two Corinna lots planted with different weight of tubers and different extent of inter-tuber-unit spacing. Similar results were obtained from comparisons in the bar charts.

TUBER DIMENSIONS

There were few significant differences between samples as to length and width, and none as to thickness. The Cunningham strain was longest and the Corinna strain was shortest. The mean width was greatest for the Corinna lot with 3-hill skips and least for the Corinna machine-planted lot, as was true of the mean tuber weight. The Corinna strain gave the lowest L/W ratio and the highest W/T ratio while the reverse was true of the Cunningham strain. Thus the 1924 results were largely repeated. These two strains, however, were significantly different only as to the former ratio, and with respect to that ratio neither strain was significantly different from all other strains.

Comparisons in 1926

GENERAL PROCEDURE

Four of the strains—Corinna, Cunningham, B. & A., and P. E. I.—were given a final test in 1926, using somewhat different methods of determining yielding power. Two supposedly high-yielding tuber lines (H-5 and H-26) and one low-yielding

tuber line (L-1), all selected from the Corinna strain in 1922, were also included in the comparison. The Corinna strain was planted in every third row. There were four machine-planted rows of each of the six other strains, placed at equal intervals across the field by virtue of these other strains being planted in the same order all four times. A fifth set of rows was similar except for being planted by tuber units. Each row covered about 1/80 acre. The five rows of each of the six strains were compared by means of Student's method with the five corresponding adjacent Corinna rows. Corresponding pairs of tuber units also were compared. Planting was done on June 11, and harvesting on September 23 in the tuber-unit rows and on September 29 to October 1 in the others.

YIELD RATES

Because of mosaic roguing early in the season, it was possible to make 30 yield comparisons between units adjacent to rogued units on the one hand, and units adjacent to the former on the other side from the rogued unit, on the other hand. The mean pounds per unit was 7.42 in each group, showing a lack of effect of roguing with the existing conditions which included a space of three feet (about two missing hills) between units.

In the pairs of rows, in yield per acre the Cunningham strain was lowest and showed the greatest difference below the corresponding Corinna rows, with the difference significant. A high-yielding tuber line (H-5) was the highest and showed the greatest difference over the corresponding Corinna rows, with the difference significant. The results of these comparisons were confirmed or duplicated in the tuber-unit pairs. However, all differences were less than 5 per cent of the yield of the Corinna strain, which varied from 337 to 360 bushels (123 to 131 barrels) per acre in the different groups of plots as paired with one or another of the other strains for comparison.

TUBER WEIGHTS

Over 300 pounds or from 1000 to 1300 tubers were sorted for each of the four commercial strains and one of the tuber lines, from the crop planted by machine. About half as much was

sorted for each strain and tuber line from the crop planted by tuber units. The mean weight of tuber in the four strains and the one tuber line (H-26) which were planted in both places, was significantly higher in all cases for the tuber-unit crop than for the machine-planted crop. In the machine-planted crop the mean tuber weights were significantly different only in the four comparisons between the tuber line and the commercial strains. In the tuber-unit crop the mean weight was not significantly different in all of the comparisons between any strain or tuber line and the other stocks. In both crops the tuber line had the smallest mean weight (5.21 and 4.01 ounces respectively for the two crops) and the Corinna and B. & A. strains had the two greatest mean weights (about 6.00 and 4.65 ounces respectively for the two crops).

In bar charts based on the percentage of tubers by number that fell in each ounce-class, the Corinna strain has the most in the 2-ounce class in the machine-planted crop, the other strains having the most in the 3- or 4-ounce classes. In the tuber-unit crop the positions are reversed, the Corinna strain having the most in the 5-ounce class and the other strains that are in both comparisons, having the most in the 2-, 3-, or 4-ounce class.

TUBER DIMENSIONS

The mean length of 8-ounce tubers was greater for the tuber-unit crop than for the machine-planted crop in each of the five strains or tuber lines planted both ways. The difference was not significant in any strain or line, but was significant with odds over 20,000 to 1 for all tuber-unit plantings, lumped *vs.* field plantings. It is interesting to correlate this consistent difference in mean length with the mean weight of tuber already pointed out as being larger in the tuber-unit crop. Similarly the mean width was consistently greater for the tuber-unit crop, the difference being usually significant. On the other hand, the mean thickness was greater for the tuber-unit crop in only one strain.

Comparing the different strains in the machine-planted crop, there was no significant difference in length, only one significant difference in width, and none in thickness. Comparing them in the tuber-unit crop, there was no significant difference in length, and only one in width, but in thickness the P. E. I. strain was signifi-

cantly lower than most of the other strains. The L/W ratio was about 1.25 for all the commercial strains in both crops, and the W/T ratio was about 1.30 to 1.40 in the tuber-unit crop and about 1.28 in the machine-planted crop for each strain.

GENERAL CONCLUSIONS REGARDING FIRST SERIES OF GREEN MOUNTAIN STRAINS

From the preceding accounts of the yearly comparisons, the writers have drawn general conclusions regarding yields, tuber weight, and tuber type.

In yields there were practically no significant differences in 1923, the Corinna strain being highest and yielding about 19 bushels or 7 barrels per acre more than the Ball strain which was lowest. In 1924 the Corinna strain was below the B. & A., H. & C., and P. E. I., while the Ball again was lowest with the Cunningham like it. In 1925 the Corinna was highest with the B. & A. low and with the Ball lowest. The Cunningham was lowest in 1926, the Ball strain having been discarded. Thus the Ball, with somewhat more disease, was consistently the lowest when tested and the Corinna strain, possibly a different variety, was most consistently the highest.

TABLE 4

Green Mountain Strain Comparison 1922-26 in Yields, Bushels Per Acre[1]

Strain	1923	1924	1925	1926	1923–25[2]	1923–26[3]	1924–26[4]
Ball	432	400	365	—	399	—	—
Corinna	450	415	406	347	424	405	389
H. & C.	464	429	368	—	420	—	—
Cunningham	—	378	396	334	—	—	369
B. & A.	443	392	365	344	400	386	367
Rich	456	387	369	—	404	—	—
P. E. I.	439	399	383	354	407	394	379
Reeves	—	393	—	—	—	—	—
All	447	399	379	345	409	395	376
Corinna, B. & A., and P. E. I.	444	402	385	348	410	395	378

[1]With two exceptions, each yield is an average for from 3 to 9 plots.
[2]The Corinna strain was not significantly superior to the Ball or Rich strains here, according to Student's method, odds being 20.4 and 6.24 respectively.
[3]The Corinna strain was not significantly superior to the B. & A. or P. E. I. strains here, according to Student's method, odds being 15.7 and 10.0 respectively.
[4]The Corinna strain was not significantly superior to the Cunningham strain here, according to Student's method, odds being 12.8.

The yields in bushels per acre for the different strains in different seasons, are arranged for examination in Table 4. There is a marked progressive decline from year to year for most individual strains and for averages of several or all strains. However, this does not necessarily prove the popular idea that shifting of seed is desirable, or indicate that an undetected disease was increasing. The Ball strain yielded only 262 bushels an acre on this farm in 1922, and the Corinna strain yielded 379 bushels an acre here in 1927. There is also a rather high correlation (.59± .18) between the yield rate of one or both (averaged) of these two strains for the six years 1922 to 1927 and the average yield rate for Aroostook County (73, p. 10). This indicates a run of progressively less generally favorable seasons in the region from 1923 to 1926 as the cause of the progressive yield decline in these strain comparisons. Aside from this decline, nothing is disclosed in Table 4 to be added to the conclusion of the preceding paragraph.

In 1922 and 1923 the mean tuber weight of the Ball strain was the lowest but in 1924 it was higher than that of the B. & A. strain, and it was the highest in 1925. The B. & A. strain was highest in 1923. The B. & A. and Corinna strains together were highest in 1926, the Ball strain having been discarded. Thus the B. & A. somewhat consistently ran to heavier tubers than the others.

In dimensions or dimension ratios, there were practically no significant differences in 1922, 1923, 1924, or 1926. The Ball strain was longest and narrowest in 1923. The Cunningham and B. & A. strains were shortest and widest in 1923. The Rich strain was longest and the Corinna shortest in 1924 and 1925. In L/W ratio the Ball was ahead in 1923 and the B. & A. and Cunningham last; the Rich was first and the Corinna last in 1924; the Cunningham was first and the Corinna last in 1925. In W/T the Cunningham was first in 1923 and last in 1924 and 1925.

The results of determinations of the L/W ratio for the different strains in different seasons, are presented in Table 5. It is evident that the seasonal averages of all strains varied little, and that the strain averages of several seasons differed just as little from each other.

Therefore the relative position of the strains in regard to most of the various characteristics tended to change from season

to season, one strain in several instances going from lead to rear, or the opposite, in subsequent years. Further, the average differences shown by the various strains over a period of several years were too small, on the basis of the characteristics studied, to make preference practical.

TABLE 5

Green Mountain Strain Comparison 1922-1926 in Regard to L/W (Length:Width) Ratio of 8-Ounce Tubers

Strain	1922	1923	1924	1925	1926	1923–25		1922–26	
						Number of tubers measured	Average L/W ratio[1]	Number of tubers measured	Average L/W ratio[1]
Ball	1.31±.018	1.32±.014	1.25±.013	1.27±.014	------	150	1.28±.008	------	------
Corinna	1.32±.014	1.29±.012	1.23±.078	1.25±.006	1.27±.009	340	1.26±.005	495	1.27±.004
H. & C.	------	1.28±.011	1.27±.013	1.27±.012	------	150	1.27±.007	------	------
Cunningham	------	1.21±.015	1.26±.014	1.30±.012	1.25±.011	135	1.26±.008	------	------
B. & A.	1.20±.016	1.24±.012	1.25±.011	1.28±.015	1.26±.010	142	1.26±.007	276	1.25±.006[2]
Rich	1.21±.021	1.29±.013	1.28±.015	1.28±.011	------	150	1.28±.007	------	------
P. E. I.	1.25±.010	1.30±.013	1.27±.014	1.30±.013	1.25±.009	150	1.29±.008[3]	292	1.27±.005
Reeves	------	------	1.24±.015	1.26±.012	------	------	------	------	------
Total number of tubers measured	174	335	450	532	372	------	------	------	------
L/W (simple average regardless of strain)	1.26±.007	1.28±.005	1.25±.004	1.27±.004	1.26±.005	------	------	------	------

[1]These are simple averages of the annual means and do not take account of the fact that more tubers are represented some years than others. Straight arithmetic averages from the total sums, regardless of the years, were found to be identical in most cases to the simple averages given here. The only discrepancies occurred in the Corinna and B. & A. strains and here it was only a matter of 1 in the second decimal place.

[2]Not significantly less than the Corinna or P. E. I. strains, according to Student's method, odds being 4.35 and 22.9 respectively.

[3]Not significantly more than the Corinna or B. & A. strains, according to Student's method, odds being 16.4 and 6.69 respectively.

Conclusions regarding the effect of various conditions within the same strain, and regarding the tuber lines, will be submitted in later sections on these subjects.

COMPARISON OF GREEN MOUNTAIN STRAINS, SECOND SERIES (1927)

ORIGINS OF STRAINS

In a second series of Green Mountain strains, compared in 1927, the Corinna strain was continued from preceding years, and tuber lines H-26 and L-1 were continued from the preceding year. Part of the Corinna strain that had been taken to Highmoor Farm in southwestern Maine in 1924 and rogued there annually, was brought back to Aroostook Farm. Four other Green Mountain strains were introduced, as follows:

Dimock strain. Secured from Vermont as of a high-yielding strain (Dimock-16) originating as a nine-pound hill (*23*) and grown in Vermont in 1926. Shipment received at Aroostook Farm in November, 1926.

Grant strain. Secured from New Hampshire as having been grown there by the shipper for 30 years and as being nearly free from disease. Shipment received at Aroostook Farm in December, 1926.

Martin strain. Secured from south central Maine near Corinna, as of a tuber line selected for good type in 1924 and grown disease-free in that locality in 1926. Shipment received at Aroostook Farm in November, 1926.

McCain strain. Secured from the Dominion of Canada Experimental Station at Fredericton, New Brunswick, as grown there in 1926. Shipment received at Aroostook Farm in November, 1926. It was learned by Dr. W. J. Morse of this Experiment Station, when visiting in that locality, that this strain had come originally from a single potato brought from Aroostook and given to McCain about 1910.

Thus this comparison was made of freshly introduced strains from southwestern Maine, south central Maine, New Brunswick, New Hampshire, and Vermont, and one grown in Aroostook County, the first and last strains tracing back to a common origin.

GENERAL PROCEDURE

This series of strains was grown together only in 1927. For yields, the eight stocks, representing the six strains and two tuber lines, were grown in eight rows which were 3 feet apart. Each stock was planted in eight 50-foot sections, equally distributed among the eight rows. The arrangement is given in Chart 1. By this arrangement there were eight tiers of sections extending across the eight rows, and the eight strains were distributed equally in the eight sections, as well as in the rows as mentioned above.

a	b	c	d	e	f	g	h
h	g	f	e	d	c	b	a
d	f	b	h	a	g	c	e
e	c	g	a	h	b	f	d
b	d	a	f	c	h	e	g
g	e	h	c	f	a	d	b
c	a	e	b	g	d	h	f
f	h	d	g	b	e	[illegible]	c

CHART 1. Arrangement of the sections in the second series of Green Mountain strains. The letters a to h represent respectively the strains Corinna, Corinna from Highmoor Farm, Dimock, Grant, Martin, McCain, H-26, and L-1. Each vertical column represents a potato row and each horizontal line represents a tier of sections across the rows. For further details see the text.

Each of the 64 sections consisted in turn of eight tuber units planted with 7-ounce tubers. Each tuber unit consisted of four hills at one-foot intervals with a missing hill between units. About eight per cent of the tuber units were rogued for disease, mostly mosaic. In each section the remaining tuber units with perfect stand were dug individually and the yield averaged. The section averages thus obtained were in turn used to get the mean yield for each strain.

For tuber sorting, samples were taken from a seed plot in which the tubers, varying both with the strain and within the strain as to weight, were planted by tuber units with a horse-drawn machine (*9; 36*).

YIELD RATES

The Highmoor Farm part of the Corinna strain yielded the most, 403 bushels or 147 barrels an acre. This was about 29 bushels or 11 barrels or 8 per cent more than the lowest-yielding strains. One of the lowest yielding strains was the supposedly high-yielding (Dimock) tuber line. (One other, tied with it in yield rate, was the Grant strain.) The Aroostook Farm part of the Corinna strain yielded only 5 bushels more than the lowest strains, which is much below the other part of the Corinna strain. The only difference which is significant, and that only slightly so, is that between the highest and lowest yielding strains.

Considering now the yields by rows, with each row containing all eight strains represented equally in the mean yield, we find a difference of 19 per cent between the extremes, with the odds great that the difference is significant. The yields by strips or tiers across the rows show a difference of 13 per cent between the extremes, with the odds rather great that the difference is significant. These differences justify the pains taken to distribute each strain equally among the various rows and strips. They also make more striking the lack of great differences between strains in the first series when the field technique was not so elaborately planned to compensate for uncontrolled field differences.

TUBER WEIGHTS

As pointed out above, the size of the seed tubers varied in the seed plot where the samples were obtained. Also the amount of roguing varied. The average weight varied from 4.11 ounces in the Grant strain to 5.44 ounces in the Aroostook Farm part of the Corinna strain. In a bar chart, by number of tubers the peak was in the 3- or 4-ounce class for every strain.

The Aroostook Farm part of the Corinna strain was planted also in certain fertilizer plots. The mean weight of tuber was found to be 2.37 ounces with no fertilizer, 4.31 ounces with 1500 pounds per acre of 5-8-7 fertilizer, and 5.46 ounces with 3000 pounds per acre. These means were significantly different. Thus in the same strain the difference between 1500 and 3000 pounds of fertilizer was correlated with about the same difference in tuber

weight as was obtained between the extremes in the strain comparison. By tuber number, the largest (modal) class with no fertilizer was the 2-ounce, the largest class with 1500 pounds was the 4-ounce, and the largest class with 3000 pounds was the 6-ounce. By aggregate weight of crop, the same was true.

TUBER SHAPES

The 8-ounce tubers secured by sorting were measured for dimensions. The Grant strain gave the greatest average length, the Aroostook Farm part of the Corinna strain ranked next, and the Highmoor Farm part of the Corinna strain was shortest, with no significant difference between any two strains. No comparison between any two strains gave a significant difference as to width or thickness, except one in width which was only slightly significant. Comparisons in dimension ratios gave no significant differences between the two parts of the Corinna strain, which had mean ratios about at the extremes in the range for the different strains.

TABLE 6

Arbitrary Classification of 8-Ounce Tubers as to Type in the Second Series of Green Mountain Strains, 1927

Strain	Percentage of classified tubers of 8 types[1]							
	(1) Spherical	(2) Short cylindrical	(3) Standard type	(4) Too flat for No. 3[2]	(5) Too long for No. 3	(6) Pointed at rhizome end	(7) Pointed at bud end	(8) Twisted, knotted or otherwise entirely off-type
Corinna A. F.	3.4	25.8	42.7	14.6	4.5	5.6	3.4	0
Corinna H.F.	8.7	23.9	43.5	12.0	5.4	1.1	4.3	1.1
Dimock-Vt.	10.3	23.5	41.2	13.2	2.9	7.4	1.5	0
Grant-N.H.	6.0	17.9	56.0	10.7	2.4	1.2	5.9	0
Martin-Dexter	2.0	24.2	56.5	11.1	3.0	2.0	1.0	0
McCain-N.B.	9.7	19.4	46.2	16.1	2.2	2.2	1.1	3.2
Total	6.5	22.5	48.0	13.0	3.4	3.0	2.9	0.8

[1]See Fig. 17 for illustrations of the various types.
[2]But fitting measurements of "ideal" Green Mountain tubers the best; see text, p. 8 and 72, and Table 10.

The 8-ounce tubers also were classified according to their resemblance to one or another of a group of selected specimens modeled in plaster of Paris (Fig. 17 and Table 6). As shown in Table 6, no one strain departed much from the average of all six strains, in any one class. The strain with the most tubers in the spherical and pointed-at-stem-end classes happened to be one rather recently originated in a single hill (Table 6, Dimock).

COMPARISON OF COMMERCIAL STRAINS OF THE IRISH COBBLER, SPAULDING ROSE, AND BLISS TRIUMPH VARIETIES (1923)

In 1923, five commercial Irish Cobbler strains, four commercial Spaulding Rose strains, and three commercial Bliss Triumph strains were grown in the same seed plot with the commercial Green Mountain strains compared above (p. 15-19). Except for an intervarietal test in 1924, these 12 strains were discontinued because of the growing evidence that we did not yet understand these varieties as to degeneration diseases, even as to those that had been studied well in Green Mountains.

In passing, it may be noted that, in any one variety, the strains above were apparently similar after the roguing of plants showing recognizable diseases. Two Irish Cobbler strains were compared as to tuber dimensions. One of these strains was claimed by the grower to have been originated by him from a seedling plant. In tuber dimensions it showed no significant differences from a commercial strain of another source, and in general appearance there was no difference.

Two Bliss Triumph strains were compared in 1924 as to L/W and W/T ratios. Tubers of this variety when grown in Nebraska had a greater L/W ratio than those grown in Maine, even when tubers were split, halves grown in the two regions, and the progenies compared (*130*). The two strains compared here were respectively from Nebraska and Maine. The ratio differences between them were not significant.

COMPARISONS OF TUBER LINES SELECTED WITHIN A COMMERCIAL STRAIN

Aroostook Farm Selections for Yield in the Corinna Green Mountain Strain

ORIGINAL SELECTION

In 1923, tuber lines[10] were selected in the Corinna Green Mountain strain. This was done in rows which had been planted by 4-hill tuber units, by hand, using 4-ounce tubers, with no skips between units. The rows where these selections were made had been prepared for planting by furrowing them out and applying about 1500 pounds of 5-8-7 fertilizer per acre. The fertilizer was applied in the furrows and mixed with the soil, by machine. The seed pieces were uniformly spaced, with the aid of a marker, one foot apart in the row, and were covered as soon as possible after planting—within 5 to 9 hours. The customary cultural and spraying operations were followed throughout the season.

At about the time of the normal date of the autumnal killing frost, *viz.*, September 18-20, 400 units were dug, as they came in the row, except for the omission of those next to rogued units. The yield of each unit was determined, and selection was made of the 40 highest- and the 40 lowest-yielding units. These were designated individually as H-1, H-2, H-3, ... H-40, and referred to collectively as the high-yielding tuber lines. The low-yielding selections were designated individually as L-1, L-2, L-3, ... L-40, and known collectively as the low-yielding tuber lines. For this work it would have been better to have 2 or 3 skips between each unit and the next. However, special care was taken to note the origin of tubers at the ends of the tuber units during the digging, which was done by hand by one of the writers. It may be noted that the low-yielding tuber units ranged in weight of crop from 2 pounds 15 ounces to 5 pounds 11 ounces, while the high-yielding tuber units ranged from 8 pounds to 10 pounds 12 ounces. The average weight of the high-yielding tuber units was 8 pounds 11 ounces, or about 80 per cent more than the average yield of the low-yielding tuber units which was 4 pounds 13 ounces.

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[10]For definition of "tuber line" see fifth paragraph of the Introduction of this bulletin.

Of the 40 low-yielding units, 9 had one or more hills obviously weaker than the others, and two were at the ends of rows and may have received insufficient fertilizer. Of the 40 high-yielding units, 4 had one or two neighboring hills (in the next units) weak or missing. The remainder, constituting a great majority, were either low- or high-yielding without any apparent cause.

The weaker hills, just referred to, probably were different due to longitudinal splitting of the seed tubers. Bushnell has found that that manner of quartering gives rise to variation due to a weakening of some sprouts from being too near to the cut surface (*17*). Bushnell did not take yields, but in our tests there was a 10 to 20 per cent difference in yield favoring rows planted with blocky seed pieces secured by cutting the tubers once lengthwise and then crosswise, over the rows planted with slender seed pieces secured by cutting the tubers twice lengthwise. This necessitated a correction in the selection of low- and high-yielding units to make them comparable regardless of the two methods of planting.

The tubers of each selection were put into properly labeled sacks and stored over winter in a typical potato storage cellar.

COMPARISONS IN 1924

The 40 high-yielding and 40 low-yielding tuber lines were paired in 1924 according to number, H-1 against L-1, H-2 against L-2, etc. This was done in 40 rows, a pair to each row. The rows were 60 feet long and 3 feet apart, and the seed pieces were planted at 12-inch intervals. In each row were planted 5 tubers of each of the two paired tuber lines. If possible, the five tubers weighed respectively 4, 5, 6, 7, and 8 ounces. A typical row is as follows: H-1, 4 ounces; L-1, 8 ounces; H-1, 5 ounces; L-1, 7 ounces; H-1, 6 ounces; L-1, 6 ounces; H-1, 7 ounces; L-1, 5 ounces; H-1, 8 ounces; and L-1, 4 ounces. Alternating rows started with a 4-ounce tuber of a low-yielding line instead of a high-yielding line.

The tuber units were dug individually and the average yield per hill determined for each tuber unit. This varied a little with the weight of the seed tuber, ranging in the low-yielding series from 23.7 to 25.1 ounces per hill, ranging in the high-yielding

series from 23.9 to 27.6 ounces per hill, and increasing with a decrease in weight of seed tuber in each series.

This effect of weight of seed tuber in 1924 seemed to be about as great as the effect of original (1923) high or low yield. The difference in yield between the two series seemed to have largely disappeared. Averaging the yield per hill of the tuber units of each tuber line, there was a range of 20.9 to 29.8 ounces in the low-yielding series and a range of 19.9 to 30.7 ounces in the high-yielding series. The former averaged 24.9 ounces to 25.3 ounces for the latter. Thus the difference of 80 per cent in 1923 had shrunk to a difference of only 1.6 per cent in 1924. A comparison by Student's method did not show the difference to be significant.

It may be noted that all the units in three lines, and some of the units in two lines, were not included in the yield averages because of having "giant-hill" characteristics. These abnormally large-vined units showed a 20-per cent reduction in yield in comparison with normal units of the same tuber line.[11] Also excluded were some units in two lines, for "little-tuber" symptoms, due apparently to a new disease which reduced the yield 60 per cent.

For further comparisons in 1925 we selected, of the 40 pairs grown in 1924, nine which gave differences from 0 to 29 per cent in favor of the high-yielding line. As a tenth pair we kept the highest-yielding H line (H-30) and the lowest-yielding L line (L-13).

COMPARISONS IN 1925

In 1925, 20 rows were planted about three feet apart. In each row were 20 tuber units, all planted either from 4-ounce tubers or from 5-ounce tubers. The seed pieces were cut to aver-

[11]In some years other characteristics appear—the period of flowering is lengthened, the growing season is lengthened by resistance to early autumnal frosts severe enough to kill all other vines, and sprouts and nipples appear on the bud ends of the tubers, not all these characteristics necessarily appearing together in any one season. It was thought either that "giant hill" was a disease related to spindle tuber, or that it was a varietal admixture. If the latter, it is not known how some of the tuber lines could have been only part "giant-hill", except through error in handling.

age an ounce each, and were planted at 12-inch intervals except for 3 empty hills between 4-ounce units and 2 empty hills between 5-ounce units. Thus each unit took 7 feet of row. A typical row is as follows: H-1, L-1, H-1, L-5, H-1, L-8, etc. until each L line was represented. Then in the next row, 10 tubers of an L line were alternated with 10 tubers of the 10 H lines, respectively.

After the individual tuber units were dug and their yields determined, the 10 tuber units representing 10 different tuber lines were averaged for each row, to disclose variation of the same stock among the various rows. To show variation along the rows, the tuber-unit yields were averaged by strips across the rows. Also, of course, in each row the 10 tuber units common to a high- or low-yielding line were averaged against the other 10 units representing 10 different tuber lines which were supposedly of the opposite yielding power.

The average yield of similar groups of units varied more from row to row, and from strip to strip across the rows, than the greatest difference between a low-yielding series and the corresponding high-yielding series. The last was 15 per cent. Altogether the H series of lines averaged about 3 per cent more than the L series. From 156 pairs of adjacent units, the difference obtained is 4.89 ± 1.12 ounces with odds that the difference is highly significant.

In a similar comparison between tuber units of four H lines and of 7 commercial strains, the mean difference between paired units was 1.314 ± 0.435 ounces, in favor of the H lines, with the difference statistically significant.

COMPARISONS IN 1926 AND 1927

In 1926 and 1927 some tuber lines of this series were continued in the comparisons of commercial Green Mountain strains, as has been shown in preceding pages.

A high-yielding tuber line (H-5) was the highest in yield in 1926 and showed the greatest difference over the corresponding rows of the bulk or unselected stock of the mother (Corinna) strain. Another supposedly high-yielding tuber line (H-26) yielded low and gave the next to the largest difference below the corresponding Corinna rows. Also departing from name, the

supposedly low-yielding tuber line (L-1) this year was next to the H-5 line in yield and in difference over the mother strain.

In 1927, the H-26 and L-1 tuber lines were compared with the new series of commercial strains including the mother Corinna strain. The H-26 yielded like the lowest commercial strain while the L-1 yielded better than the Corinna strain.

In 1926 the H-26 tuber line had a significantly lower mean tuber weight than the commercial strains in the machine-planted comparison. Here the other tuber lines were not compared. All three tuber lines were compared with the commercial strains in the tuber-unit comparison, where the H-26 was again lowest, but not so distinctly so, while the other two were about midway in the series. The tuber lines were not sorted for tuber weight in 1927.

Tuber dimensions were not significantly different in 1926 between line H-26 and the commercial strains except in width, where H-26 was lower. Line H-26 had the highest index for L/W ratio in the machine-planted comparison, where the other two lines were not included. In the tuber-unit comparison of the same year, lines H-5 and H-26 had the highest L/W ratios. No measurements of tubers were made in the tuber lines in 1927.

By 1927 the mosaic content of lines H-26 and L-1 had become too great to permit further study.

CONCLUSIONS ON AROOSTOOK FARM SELECTIONS IN THE CORINNA GREEN MOUNTAIN STRAIN

In 1924 and 1925, tuber lines selected in 1923 for high yield, as a group gave some difference over another group selected in 1923 for low yield. However, the difference was much less than in 1923, was small (about 1.6 per cent in 1924 and about 3 per cent in 1925), and was not shown by 2 out of 3 lines carried on through 1926 and 1927. It is concluded that tuber-line selection as a growers' practice is not to be recommended on the basis of this test, in view of the smallness of gain, the labor involved, and the danger from degeneration diseases. Hill selection is considered to be still less reliable, because the chances of a hill being different solely on account of environmental conditions seems to be much greater than the chances of the average of a group of consecutive sister hills such as a tuber unit.

TUBER TYPE COMPARISONS IN SPAULDING ROSE AND GREEN MOUNTAIN STOCKS IN 1927

GENERAL PROCEDURE

In April, 1927, a sample of Spaulding Rose tubers was received from Mr. E. L. Newdick, the chief of the State potato seed certification service, as having been taken from certified stock because of a complaint as to type. From the grower, in Mapleton, in Aroostook County, another lot of Spaulding Rose tubers was secured, selected by one of us as of good type. These two lots will be known here as "poor-type" and "good-type" Spaulding Rose. The principal defect in each tuber of the "poor-type" lot was noted, with findings as follows:

20 tubers deformed by some depression like those due to rocks.
13 with eye-end too pointed to be of good type.
6 with outline too bumpy, especially beneath the eyes. "Possibly giant-hill"
2 with stem-end too pointed.
2 possibly spindle-tuber and also scabby, including 1 distinctly spindle-tuber.
2 with too much scab.
1 forked (one stem end but two bud ends).

In May, 1927, Mr. Newdick wrote that the certification service was having difficulty over complaints regarding a Green Mountain type of tuber that is "nearly round all but the stem end which apparently seems to be flat". Consequently when sorting the Aroostook Farm Green Mountain crop (Corinna strain) kept from a 1926 spray test, tubers were laid aside in four groups—(1) those of an exhibition type, (2) those with the stem end small, (3) those with the bud end small, and (4) those with spindle-tuber shape. Authentic giant-hill stock was obtained from the disease-perpetuation stocks under the charge of Dr. E. S. Schultz of the U. S. Department of Agriculture, originating, at least in part, from the hills described previously (p. 56).

Before planting these stocks, each tuber was recorded in profile by outlining the shadow as made by a light above the dorsal face (see previous section on General Methods, Measurement of Tuber Shape). Time did not permit making a plaster cast and duplicate model of each one. Planting was done by tuber units.

Without using the profile records for reference, the tuber units were examined in late July as growing plants and notes on their appearance were recorded. After the vines had been killed by frost, most of the tuber units were dug. The tubers of each unit were sacked together, separate from the other units, and examined later for the following characteristics:

Close likeness to parent tuber in facial outline.
Approximate conformity to ideal oblong type in outline, face view.
Preceding conformity accompanied by absence of any defect like those listed below, resulting in exhibitable tuber.
Cylindrical shape.
Roundness in facial outline.
Stem end too pointed.
Bud end too pointed.
Bumpiness of surface.
Length too great in proportion to width and thickness.
Width too great in proportion to length and thickness.
Thickness too great in proportion to length and width.
Growth crack.
Rock-formed dent.
Agropyron-formed groove.[12]
Knobbiness due to "second growth".
Rhizoctonia deformation.
Wasp-waisted form.
Forked form—two bud ends from one stem end.

The various comparisons of records regarding seed tubers, vines, and harvested tubers, gave rise to a number of conclusions, which will be stated briefly without the details of the evidence.

RELATIONS OF VINES AND TUBERS AS TO TYPE

The difference in shape between the two Spaulding Rose lots did not indicate what could be expected of the vines, as each of the two lots had about 80 per cent of the tuber units with large and "staring" vines. In the good-type group this kind of vine tended to give harvested tubers that were better than the average, while the opposite was true in the poor-type group. In each group there were no consistent and marked differences in the harvested tubers to correspond with the vine type.

[12] Agropyron is commonly called "witch grass".

In the Green Mountains the exhibition-type group of seed tubers happened to give the highest percentage of mild mosaic in the vines. There was no correlation between mild mosaic and the type of harvested tubers. One seed tuber of the spindle-tuber lot when outlined was noted as "not of good spindle-tuber type" and was the only one of this group to produce healthy vines and good-type harvested tubers. Among the other four groups of Green Mountain seed tubers, four tubers were suspected when outlined of being spindle-tuber, and one of these four was the only one to give spindle-tuber vines and yield. Thus outlining helped to make selection for spindle tuber more critical, but the spindle-tuber disease was not always found in the vines and harvested tubers when suggested by the shape of the seed tuber. In the Green Mountains the giant-hill stock gave vines characteristic of those of preceding years, but the harvested tubers were not distinctly different from those of the other stocks, as they are in some seasons. Several seed tubers noted in the other lots as being possibly giant-hill gave no characteristic giant-hill vine symptoms. Therefore one cannot be entirely sure of picking either spindle-tuber or giant-hill stock out of partly diseased stock, judging by tuber shape alone. Some of the suspected tubers will produce healthy vines.

RELATIONS OF SEED AND HARVESTED TUBERS AS TO TYPE

In profile, even in the spindle-tuber lot, which differed as a whole from the other lots, there was close likeness to the seed tuber in only about 18 per cent of the harvested tubers. This percentage was not exceeded in any other lot.

Approximate conformity to the ideal oblong type in outline was found in very few of the spindle-tuber group. (Fig. 6, series S.) It was most marked in the group with small bud ends (37 per cent). In the Spaulding Rose lots it was more pronounced as more tubers, that is, as smaller tubers, were included in the examination. The tubers with both conformity and freedom from any listed defects, ranged from none in the spindle-tuber group to 17 per cent in the group with stem end small (Fig. 6, series R) and 19 per cent in the group with bud end small (Fig. 6, series E).

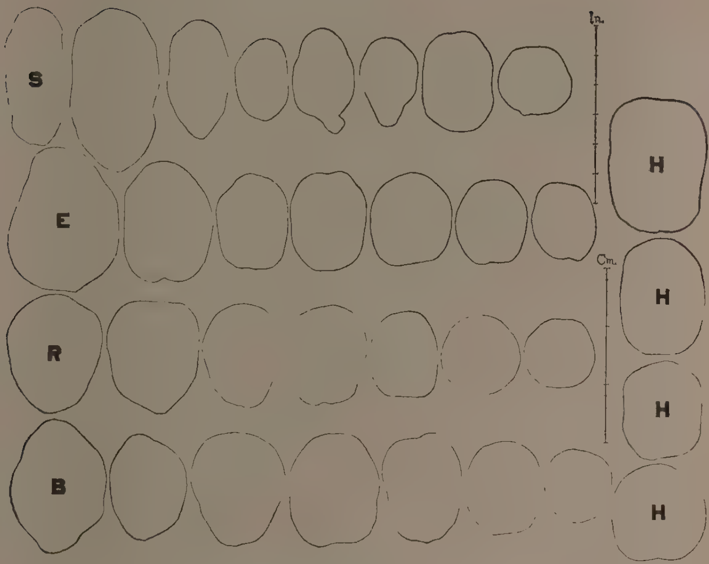

FIG. 6. Profiles of Green Mountain tubers of the 1927 study of relations of seed and harvested tubers as to type. Scales are given in inches and centimeters. The 8 lettered profiles are of seed tubers—S, spindle-tuber; E, pointed at eye or bud end; R, pointed at stem or butt end; B, pointed at both ends; H, healthy or approaching ideal in profile face-view. At right of each seed tuber S, E, R, or B, first come the two harvested tubers that are most like the seed tuber; then come profiles representative of the remaining harvested tubers. Note the tendency of the representative harvested tubers to resemble the healthy type rather than the seed tuber, especially where spindle tuber is not present. See Figs. 1 and 7 for other profile studies.

Very few tubers were cylindrical except for the great majority of the spindle-tuber group.

Roundness in facial outline was most common in the giant-hill group and about the same for the other Green Mountain groups excluding the one with spindle tuber.

Pointedness at the stem end was shown by 90 per cent of the spindle-tuber group and by 19 to 27 per cent of each of the other groups.

Pointedness at the bud end was shown by 90 per cent of the spindle-tuber group and by 23 to 32 per cent of each of the

other Green Mountain groups. In between lay the Spaulding Rose groups with more bud-end pointedness shown by the off-type lot and by the larger tubers of each lot.

Bumpiness of surface was negligible except for being in 12 per cent of the giant-hill lot and in 22 per cent of the spindle-tuber lot.

The length was too great for the width and depth in 88 per cent of the spindle-tuber lot, but not to any extent in the other Green Mountain groups. This characteristic was more pronounced in the Spaulding Rose off-type lot than in the other lot of this variety.

The width was too great for the length and depth in practically none of the spindle-tuber group, in 27 per cent of the giant-hill group, and in 8 to 18 per cent of the other lots.

The depth was too great for the length and width, without the tuber being scored as cylindrical, in a greater proportion of the exhibition and giant-hill Green Mountain lots than in the others.

Growth cracks were most abundant in the spindle-tuber lot, but were found in only 4 per cent of this group.

The only other noteworthy characteristic was rock denting, which varied from 2 per cent in the spindle-tuber lot to 13 per cent in the giant-hill lot.

The results of the preceding comparisons between groups of tuber units oppose the idea of inheritance of certain readily distinguished shape characteristics in the Green Mountains except those symptomatic of giant hill and spindle tuber.

COMPARISONS OF COMMERCIAL STRAINS DESCRIBED AS BEING TUBER LINES

STRAINS USED IN PRECEDING COMPARISONS

In the comparisons described in the preceding pages of this bulletin there were included several commercial strains that were claimed to have been originated as tuber lines. (Here origin in a single hill or seed piece is considered as equivalent to origin in a single tuber.) Reference may be made profitably to the results of those comparisons, with this kind of origin especially in mind.

In the comparison of Green Mountain strains, second series, in 1927, the Dimock, Martin, and McCain strains were included and were described as having originated as tuber lines or equivalent hill selections. In yield rate these were not distinctive, except possibly for one that was selected originally for high yield being here one of the lowest-yielding strains. In average tuber weight these three strains fell within the extremes. In tuber dimensions they also fell within the extremes and there were practically no significant differences between any strains. In the classification based on resemblance to type models, there were no great differences, and the strain with the most tubers in certain poor-type classes was one of the three tuber lines. In relation to this lack of uniformity in tuber lines, it should be mentioned that the Martin strain had been originated chiefly on the basis of good type shown when the tuber line was new.

In the comparison of Irish Cobbler strains made in 1923, described previously, a strain claimed to be a tuber line was similar to other commercial strains.

Comparisons of 1928

Reference was made in the preceding section to a Martin tuber-line commercial strain. In the fall of 1927 the farm of the originator, Mr. Martin, was visited by the senior writer. On Aroostook Farm in 1927, in similar conditions, the Martin strain had not appeared different from the other strains. On the Martin farm this strain when grown in a more sandy soil was producing tubers of much better type than on Aroostook Farm. Superior type was apparent also in several selected "superior-type" tuber lines, grown in the sandy soil referred to, when compared with other stock grown on the Martin farm in a heavier soil where the vines were living longer and producing apparently larger tubers and larger yields. Arrangements were kindly made by the grower to ship a small lot of selected tubers of a superior-type tuber line and a similar lot from the bulk stock, for further comparison on Aroostook Farm in 1928. These were grown in comparison with the Corinna strain. The amount of vine disease (mild mosaic) was small and no differences were apparent in vine growth. At digging, several barrels of each lot were sorted for tuber weight and the 8-ounce tubers were compared

as to type. Between the means of 50 tubers of the superior-type tuber line, of 100 tubers of the bulk stock, and of 82 tubers of the Corinna strain, there were no significant differences in length, width, L/W ratio, or W/T ratio. There were differences in thickness that possibly were significant, between the mean of the superior-type tuber line and the means of the other two lots, but there was also a significant difference, practically as large, between the means of 50 tubers of the bulk stock grown in one row and 50 tubers of the same stock grown in another row 9 feet distant. Therefore location in the field seemed to be as good a basis as tuber-line selection for explaining such significant differences as may have been disclosed.

The dozen 8-ounce tubers coming closest to agreement with the average dimensions, were kept from the selected tuber line and from the bulk stock, respectively. These are shown in Figs. 18 and 19. In profile, paired off, they are shown in Fig. 7. They were judged by several potato specialists and leading growers whose individual choices between the two lots varied. Therefore on Aroostook Farm, at least, the effect of past selection of a tuber line for superior type, did not have any distinctive effect.

Compared with an exhibit from the same stocks as grown by Mr. Martin in central Maine, the type of the Aroostook Farm samples of the Martin lines was distinctly inferior. In fact, Mr. Martin's exhibit at the annual fall State show narrowly missed securing first prize, being disbarred on variation in weight, while at Aroostook Farm, in the six or more barrels that were sorted, there was only one tuber that was fit to be entered in such a show. Similarly inferior was the Corinna stock sorted at Aroostook Farm, as shown previously, while the Corinna strain as grown at Highmoor Farm, in southwestern Maine, was suitable for making up exhibits. Obviously the conditions of season and locality were distinctly unfavorable for the development of good type, in the same strains of Green Mountains, in Aroostook County as compared with other parts of the State.

STRAIN DIFFERENCES IN COMPARISON WITH DIFFERENCES DUE TO OTHER CONDITIONS

In the preceding pages of this bulletin we have given the results of comparisons of commercial strains and of tuber lines.

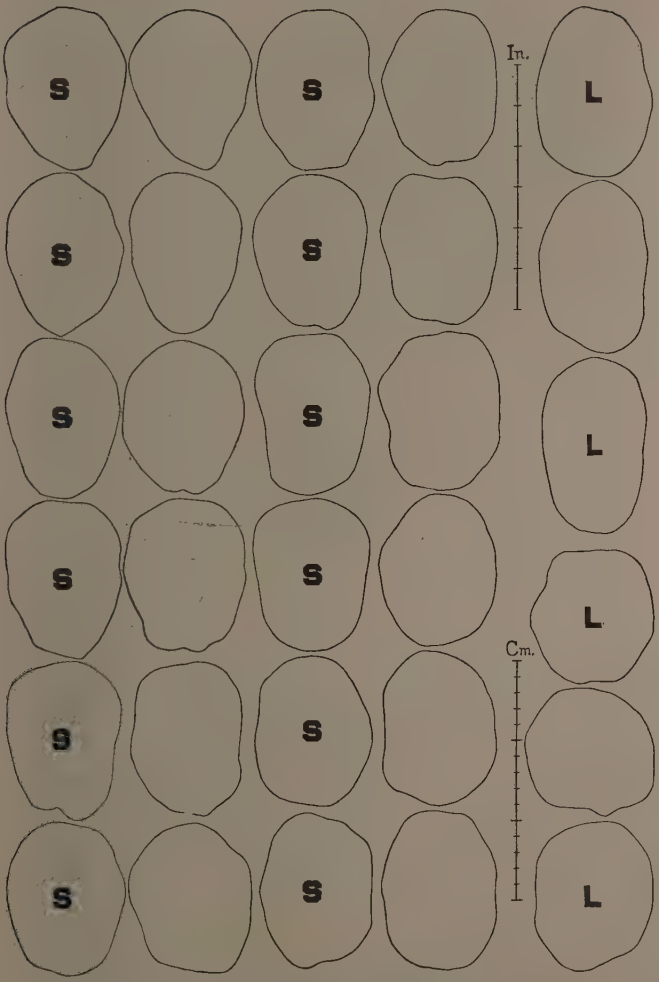

FIG. 7. Profiles of the tubers shown in Figs. 18 and 19. Marked "S" are the twelve 8-ounce tubers coming closest, in dimensions, to the average of the Green Mountain tuber line which was selected originally for good type. Paired with these to the right are the 12 coming nearest to the average of the bulk stock which was considered by the grower as inferior in tuber type. Some observers have judged the "S" profiles as better in a majority of the pairs, and some have preferred the other stock. Marked "L" are the extremes in length from the selected tuber line, and between them are the extremes from the bulk, all 8-ounce.

The comparisons have brought out some differences that seemed to depend upon strain origin. Whether these strain differences were due to unsuspected environmental factors operating during the comparison, to differences in masked-disease content, to residual effects of the environment of the preceding season, or to inherent and perpetuated differences in the nature of the strains, is not easy to ascertain. The answer can be obtained in part by comparing the strain differences, due to some or all of these factors, with differences due to other somewhat similar factors. Further, even though the answer is only partly found, it is interesting and useful to know the relative effects of strain *vs.* variety, recognizable diseases, season, location, soil, fertilizer, and various cultural conditions not already mentioned.

RELATIVE EFFECTS OF STRAIN AND OTHER CONDITIONS UPON YIELD RATE

STRAIN *VS.* VARIETY

Russet Rurals were secured in Michigan as certified stock of the crop of 1922. Stocks of all other varieties secured for the 1923 planting were grown in Maine in 1922. The Spaulding Rose stock (Higgins strain) was one of the two best ones found by us in Aroostook County, the Irish Cobbler stock (Beckwith) was the best native stock found by us in the County, and the Bliss Triumph stock (Rossignol) was the best one known in the County. (Judgment as to what was "best" was based on freedom from disease, apparent vigor, and reputation among local seedsmen and growers.) All were grown in the tuber-unit seed plot (along with the Green Mountain strains) and rogued in 1923.

The crops of all five varieties were kept in the same potato cellar in the winter of 1923-24. In 1924 all but the Bliss Triumphs were compared, as to yield rate, in the same series of plots, with replications. (The Bliss Triumphs were compared as to tuber characteristics, which are to be discussed later.) In the yield comparison of 1924, the Green Mountains were somewhat more productive than the Spaulding Rose, both were significantly more productive than the Russet Rurals, and the latter was significantly more productive than the Irish Cobblers.

TABLE 7

Comparisons of Various Causes of Differences in Yield

Comparison no.[1]	Cause of difference	Year of comparison[2]	Lots compared[3]		Higher result		Reduction by lower result		
			With higher result	With lower result	Bus.	Bbls.	Bus.[5]	Bbls.	%[4]
1	Leafroll and net necrosis	1916 (*103*, p. 51)	Healthy (not on A.F.)	Diseased (not on A.F.)	325	118	287	105	88
2	Severe net necrosis	1918 (*103*, p. 51)	Healthy (not on A.F.)	Diseased (not on A.F.)	221	80	185	67	84
3	Leafroll and net necrosis	1919 (*103*, p. 51)	Healthy	Diseased	—	—	—	—	75
4	Leafroll	1919 (*103*, p. 51)	Healthy	Diseased	—	—	—	—	74
5	Leafroll and net necrosis	1917 (*103*, p. 51)	Healthy	Diseased	274	100	190	69	69
6	Rugose mosaic	1925 (*39*, p. 70-71)	Healthy	Diseased	366	133	227*	83	62
7	Rugose mosaic	1924 (*39*, p. 65)	Healthy	Diseased	352	128	179*	65	51
8	Fertilizer	1926 (*14*, p. 17)	Ton of 6-9-6 (not on A.F.)	No fertilizer	299	109	141	52	47
9	Fertilizer	1927 (*14*, p. 19)	Ton of 6-9-6 (not on A.F.)	No fertilizer	330	120	143	52	43
10	Mosaic	1923 (*38*, p. 7)	Healthy	Diseased	370	135	111*	40	30
11	Fertilizer	1925 (*14*, p. 15)	Ton of 6-9-6 (not on A.F.)	No fertilizer	297	108	86	31	29
12	Mild mosaic	1925 (*39*, p. 70-72)	Healthy	Diseased	366	133	94*	34	26
13	Spindle tuber	1925 (*39*, p. 71-72)	Healthy	Diseased	350	127	90*	33	26
14	Variety	1924	Green Mountain	Irish Cobbler	379	138	93*	34	25
15	Season	—	Corinna, 1923	Corinna, 1926	448	163	111	40	25
16	Season	—	B. & A., 1923	B. & A., 1926	444	161	102	37	23
17	Spindle tuber	1923 (*38*, p. 7)	Healthy	Diseased	393	143	84*	31	21
18	Mosaic	1919 (*103*, p. 51)	Healthy	Diseased	—	—	—	—	20
19	Spindle tuber	1924 (*39*, p. 64)	Healthy	Diseased	403	147	76*	28	19
20	Season	—	Rich, 1923	Rich, 1925	458	167	89	32	19
21	Season	—	P. E. I., 1923	P. E. I., 1926	441	160	85	31	19
22	Season	—	Ball, 1923	Ball, 1925	432	157	67	24	16
23	Season	—	Cunningham, 1925	Cunningham, 1926	396	144	61	22	15
24	Season	—	H. & C., 1924	H. & C., 1925	429	156	61	22	14
25	Spraying	1923 (*35*, p. 237-238)	No spray	Spray	411	150	58	21	14
26	Mild mosaic	1924 (*39*, p. 65)	Healthy	Diseased	352	128	45*	16	13
27	Spraying	1927 (*10*, p. 107)	Spray	No spray	368	134	46	17	13
28	Strain	1924	H. & C.	Cunningham	429	156	51*	19	12
29	Field	1924	Field A	Field B	403	147	50	18	12
30	Variety	1924	Green Mountain	Russet Rural	379	138	41*	15	11
31	Strain	1925	Corinna	Ball	406	148	41*	15	10

TABLE 7—Concluded.

Comparison no.[1]	Cause of difference	Year of comparison[2]	Lots compared[3]		Higher result		Reduction by lower result		
			With higher result	With lower result	Bus.	Bbls.	Bus.[5]	Bbls.	%[4]
32	Strain	1927	Corinna	Grant	403	147	29*	11	7
33	Strain	1923	Rich	Ball	458	167	26	9	6
34	Strain	1926	Corinna	Cunningham	352	128	17*	6	5
35	Tuber-unit selection	1925	High-yielding series	Low-yielding series	—	—	—	—	3
36	Variety	1924	Green Mountain	Spaulding Rose	379	138	6	2	2
37	Tuber-unit selection	1924	High-yielding series	Low-yielding series	—	—	—	—	2
38	Giant-hill	1925 (39, p. 71-72)	Diseased[6]	Healthy	352	128	2	1	1

[1]In order of decreasing difference as expressed in the last column on the right.

[2]See Literature Cited for references, and text of this bulletin for some other data. Some data transcribed directly from records. Maximum difference for any one year, or for any one strain in reference to effect of season, given here.

[3]Lots of Green Mountain variety and on Aroostook Farm unless otherwise stated.

[4]Percentage based on pounds per hill when acre yields are not given.

[5]An asterisk (*) denotes that the difference was known to be significant.

[6]See footnote [11], on p. 39 of text. Here the one-per cent increase from giant hill was due to a week's longer growing season following the first general potato-killing fall frost of the season.

Compared with the Green Mountains (Corinna strain) the other varieties showed a reduction in yield of from 2 per cent to 25 per cent (Table 7, comparisons 14, 30, and 36). In the same season, the greatest strain difference was 12 per cent (Table 7, comparison 28). In other years, maximum strain differences were from 5 to 10 per cent (Table 7, comparisons 31, 32, 33, and 34). Thus, the difference between strains of Green Mountains was greater than the difference between some varieties, and less than the differences between other varieties.

STRAIN *VS.* DISEASE AND SPRAYING

Results in previous publications, transcribed to Table 7, show a greater reduction in Green Mountains by certain degeneration diseases than by strain differences. With maximum strain differences of 6 per cent in 1923, 12 per cent in 1924, 10 per cent in 1925, 5 per cent in 1926, and 7 per cent in 1927 (Table 7, comparisons 33, 28, 31, 34, and 32), we find reductions as follows: Leafroll or net-necrosis or both, 37 to 88 per cent in 1916, 1917, 1918, and 1919 (Table 7, comparisons 1 to 5, and 10). Rugose mosaic, 51 per cent in 1924 and 62 per cent in 1925 (Table 7, comparisons 7 and 6). Mild mosaic or mosaic (probably mostly mild), 20 per cent in 1919, 30 per cent in 1923, 13 per cent in 1924, and 26 per cent in 1925 (Table 7, comparisons 18, 10, 26, and 12). Spindle tuber, 21 per cent in 1923, 19 per cent in 1924, and 26 per cent in 1925 (Table 7, comparisons 17, 19, and 13).

Thus one or another of several degeneration diseases always showed more reduction than was recorded in five years between any two Green Mountain strains. Giant-hill, however, gave a slight increase due to its lengthened growing season (Table 7, comparison 38).

Spraying during a year when it decreased disease injury, and spray injury during a year of freedom from diseases and pests, each modified the yield more than strain difference in any of five years (Table 7, comparisons 25 and 27).

STRAIN *VS.* SEASON

Seven Green Mountain strains each showed more difference between one season and another, in regard to yield, than the

greatest difference between strains in any one season (Table 7, comparisons 15, 16, and 20 to 24, for season, and comparisons 28 and 31 to 34 for strains). To some extent this involves differences in soil, size of seed pieces, amount of fertilizer, etc., that can be modified in any one season and so are not strictly seasonal factors in the sense that rainfall, temperature, and cloudiness are.

STRAIN *VS.* LOCATION, SOIL, FERTILIZER, AND OTHER CONDITIONS

The same strain in two adjacent parts of the same field, with soil varying somewhat to correspond, differed in 1924 as much as the maximum strain difference for that or any other year (Table 7, comparisons 28, 29, and 31 to 34). In 1926 the Corinna strain varied from one group of check plots to another by 6 per cent which was more than the greatest difference between commercial strains in that year. A ton of 6-9-6 fertilizer had 2.5 to 4 times as much effect as the greatest strain difference in any one season, and 3 to 15 times the greatest strain difference found in the same season with the fertilizer comparison (Table 7, comparisons 8, 9, 11, 28, and 31 to 34).

RELATIVE EFFECTS OF STRAIN AND OTHER CONDITIONS UPON TUBER WEIGHT

STRAIN *VS.* VARIETY

The crops of the variety-comparison yield test of 1924 were not sorted by tuber weight, but parts of the same stocks were planted by hand by tuber units in the seed plot and rogued. The seed tubers weighed 4 to 6 ounces for the Bliss Triumphs and 6 ounces for the other varieties. Field-run samples of about 300 pounds each were sorted. In order of decreasing mean tuber weight the varieties ranked: Russet Rural, Green Mountain, Spaulding Rose, Irish Cobbler, and Bliss Triumph. All differences were significant except that between Green Mountains and Spauldings.

Comparing the Green Mountains with each other variety, the mean tuber weight differed from 1 to 36 per cent (Table 8, comparisons 8, 21, 22, and 27). In the same season the greatest

strain difference was 21 per cent (Table 8, comparison 15). In other years, maximum strain differences were from 2 to 32 per cent (Table 8, comparisons 10, 17, 20, 24, and 26). Thus, the difference between strains of Green Mountains was about as distinct as the differences between some varieties, especially in some seasons.

TABLE 8

Comparison of Various Causes of Differences in Mean Tuber Weight

Comparison no.[1]	Cause of difference	Year of comparison[2]	Lots compared[3]: With higher result	Lots compared[3]: With lower result	Lower result	Increase over lower result	
					oz.	oz.[4]	%
1	Fertilizer	1927	1500 lbs., 5-8-7	No fertilizer	2.37	1.94*	82
2	Season	——	Ball, 1924	Ball, 1922	4.08	3.17*	78
3	Season	——	B. & A., 1923	B. & A., 1922	4.41	3.01*	68
4	Season	——	Cunningham, 1924	Cunningham, 1926	4.58	3.09*	67
5	Season	——	Rich, 1924	Rich, 1922	4.38	2.60*	59
6	Season	——	Corinna, 1923	Corinna, 1926	4.64	2.14*	46
7	Season	——	P. E. I., 1923	P. E. I., 1926	4.57	2.09*	46
8	Variety	1924	Green Mountains	Bliss Triumph	4.95	1.78*	36
9	Size of skips between tuber units	1925	Corinna, with 3-hill skips	Corinna, with 1-hill skips	5.23	1.81*	35
10	Strain	1927	Corinna	Grant	4.11	1.33	32
11	Season	——	H. & C., 1923	H. & C., 1925	5.29	1.52*	29
12	Method of planting	1926	Corinna, tuber units	Corinna, machine-planted	4.64	1.36*	29
13	Field, method of planting, etc.	1925	Corinna Green Mountains, planted in tuber units in field A	Corinna Green Mountains, planted in standard way in field B	4.11	1.12*	27
14	Fertilizer	1927	3000 lbs., 5-8-7	1500 lbs., 5-8-7	4.31	1.15*	27
15	Strain	1924	Cunningham	H. & C. or P. E. I.	6.32	1.35*	21
16	Giant hill	1925	Diseased	Healthy	4.11	0.87*	21
17	Strain	1925	Ball	Reeves	4.54	0.80*	18
18	Selection of tubers	1925	Overweight Cunningham Green Mountains	Average Cunningham Green Mountains	5.10	0.87*	17
19	Disease and field, etc.	1925	Healthy B. & A. Green Mountains planted in tuber units in field A	Spindle-tuber B. & A. Green Mountains, planted in standard way in field B	4.48	0.75*	17
20	Strain	1923	B. & A.	Ball	6.37	1.05*	16
21	Variety	1924	Green Mountain	Irish Cobbler	5.86	0.87*	15
22	Variety	1924	Russet Rural	Green Mountain	6.73	0.64*	10
23	Spindle tuber and strain	1925	B. & A., diseased	Corinna, healthy	4.11	0.37*	9
24	Strain	1922	B. & A.	Ball	4.08	0.33*	8
25	Skips between tuber units	1924	Corinna, with 1-hill skips	Corinna, with no skips	6.73	0.11	2
26	Strain	1926	B. & A.	P. E. I.	4.57	0.08	2
27	Variety	1924	Green Mountain	Spaulding Rose	6.69	0.04	1

[1]In order of decreasing difference as expressed in the last column on the right.
[2]Data transcribed from text or from records. Maximum difference for any one year, or for any one strain in reference to effect of season, given here.
[3]Lots of Green Mountain variety and on Aroostook Farm unless otherwise stated.
[4]An asterisk (*) denotes that the difference was known to be significant.

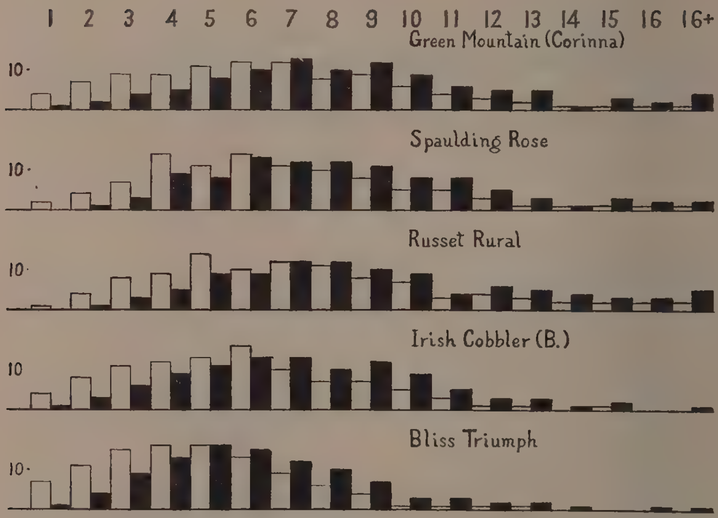

FIG. 8. Crop of 1924, five varieties compared as to tuber weight. Numbers at left indicate percentages. Numbers at top indicate weight of each tuber in ounces. The white bars by their height denote percentage of tubers, by number, of a certain tuber weight. The black bars denote percentage of crop, by weight, of a certain tuber weight. Compare with Figs. 4 and 9 for similar comparisons of Green Mountain strains and of crops of different seasons.

Fig. 8 shows the distribution in bar-chart form, and can be compared with Fig. 4 which shows the same for the Green Mountain strains in the same year. Except for the Bliss Triumphs the distribution curves appear quite similar.

STRAIN *vs.* SEASON

Of the seven Green Mountain strains, six showed more difference between one season and another, in regard to mean tuber weight, than the greatest difference between two strains in any one season (Table 8, comparisons 2 to 7, 10, 11, 15, 17, 20, 24, and 26). These maximum interseasonal differences were significant for each strain, while the maximum difference between strains was not significant in every season (Table 8, comparison 26). Further, in the Ball strain the mean tuber weight

was significantly different in every comparison between the four seasons 1922, 1923, 1924, and 1925. The Corinna strain, while not grown in these tests as early as the Ball strain, remained free of recognizable diseases longer and was used after the Ball strain had been discarded. Its mean tuber weight was significantly different in every comparison between the four seasons 1923, 1924, 1925, and 1926, except between 1923 and 1924.

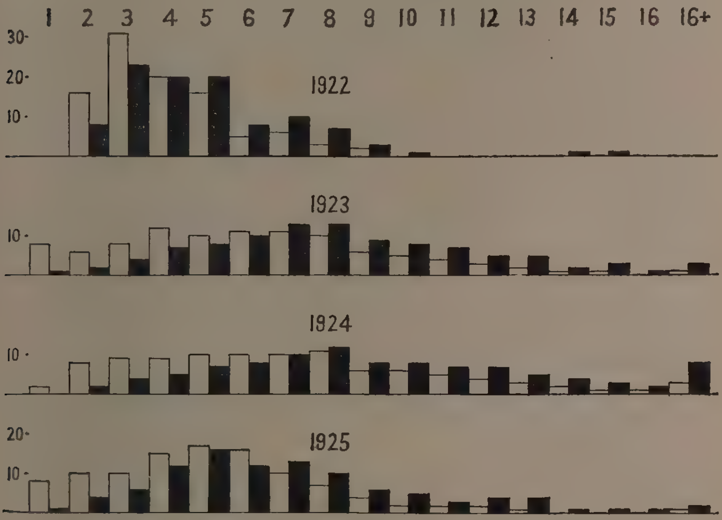

Fig. 9. Ball Green Mountain strain, crops of four consecutive seasons compared as to tuber weight. Numbers at left indicate percentages. Numbers at top indicate weight of each tuber in ounces. The white bars by their height denote percentage of tubers, by number, of a certain tuber weight. The black bars denote percentage of crop, by weight, of a certain tuber weight. Compare with Figs. 4 and 8 for similar comparisons of Green Mountain strains and of varieties.

Fig. 9 shows the distribution for the Ball strain in bar-chart form, and can be compared with Fig. 4 which shows the same for various Green Mountain strains in one year. The distribution curves in Fig. 9 are somewhat similar for 1923 and 1924, but there are 3 distinctly different types in the 4 seasons, while the curves for the different strains in any one season are quite similar.

Thus, the effect of season upon a single strain is generally greater than the strain differences of one season, whether tuber weight is judged by averages or by classes.

Both the mean weight and the peak in the distribution curve, vary to correspond with the yield rate for the season. This is true of both the Ball and Corinna strains. There is a high and significant correlation (.80 ± .08) between the mean tuber weight and the yield rate in 9 pairings that are available. This indicates that seasonal variation in yield rate depended largely upon size of tubers rather than upon number of tubers, at least in these experiments. There is also a rather high correlation (.59 ± .18) between the yield rate of one or both (averaged) of these two strains for the six years 1922 to 1927 and the average yield rate reported officially (*73*, p. 10) for Aroostook County. Less correlation would be expected here because in some years the County yield rate was lowered by foliage diseases which were controlled in our experiments. With the date of the autumnal killing frost earliest in 1923, the year of the highest yield, and ranging only from September 22 to 28 for the other years, there is no correlation between this date and yield rate or mean tuber weight.

It becomes of interest to consult the official meteorological records taken on the farm on which these strain tests were made. In 1923 it was abnormally rainy and cool in July, and there was little injury from fungous diseases. The seasons 1924 and 1925 were about like 1923 as to the weather records but witnessed much change as to tuber weight and W/T ratio, for all strains. These interseasonal changes in relative position, therefore, are at least not explainable on the basis of available meteorological records.

It should be repeated here that interseasonal comparisons are involved with some differences in soil, size of seed pieces, amount of fertilizer, and other factors.

STRAIN *VS.* DISEASE, FERTILIZER, LOCATION, AND METHOD OF PLANTING

The maximum strain differences for six seasons are given in Table 8, comparisons 10, 15, 17, 20, 24, and 26. The apparent effects of other conditions on mean tuber weight will be com-

pared with these strain differences, for the same season and for all seasons.

Planting by tuber units, either in the same field or in a different field, gave an increase that was much greater (than strain differences) in the same seasons, and comparatively great in general. (Comparisons 12 and 13.) In tuber units, the introduction of a skip had no appreciable effect (comparison 25) but the increase of the skip from one hill to 3 hills gave an increase that was great, both for the season and in general (comparison 9).

The selection of overweight tubers gave about the same increase as strain difference (comparison 18).

Spindle tuber, together with strain difference or field difference, gave an increase that was not comparatively large (comparisons 19 and 23). The same is true of giant hill in the Corinna strain (comparison 16). General observations have shown considerable decrease in tuber weight by rugose mosaic and other degeneration diseases, varying with season and locality and often apparently greater than strain differences in similar conditions.

The increase of the amount of 5-8-7 fertilizer from 1500 to 3000 pounds per acre, gave an increase that was not large for the season, though rather large in general (comparison 14). The use of 1500 pounds of that fertilizer *vs.* none at all, gave a large increase (comparison 1).

RELATIVE EFFECTS OF STRAIN AND OTHER CONDITIONS UPON TUBER TYPE

STRAIN *VS.* TUBER WEIGHT

General observations apparently have shown that the length increases faster than the width after an early stage in the growth of Green Mountain tubers, and that the larger the tuber, the greater the L/W (length:width) ratio. Accordingly in 1922 and 1923, comparison was made between 8-ounce and 4-ounce tubers of the same strain, with the L/W ratio found to be significantly greater in the former, as described previously.

In 1927, comparison was made between 4-, 6-, 8-, and 10-ounce tubers. The results (Fig. 10) were an increase in the L/W ratio with increasing weight of tuber, and rather the oppo-

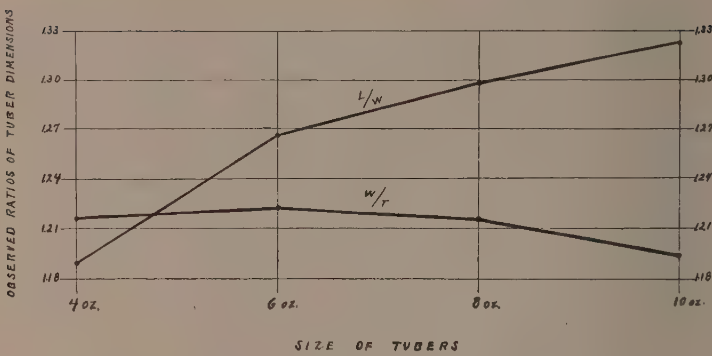

FIG. 10. Crop of 1927, comparison between 4-, 6-, 8-, and 10-ounce tubers of the same Green Mountain stock, Corinna strain, as to the ratio of length to width (L/W) and the ratio of width to thickness (W/T). See Fig. 11 for an explanation of the increase here of the L/W ratio with tuber weight, see Fig. 16 for device for measuring tuber dimensions, and see Fig. 1 for effect of L/W and W/T ratios on tuber type.

site in the W/T ratio. The explanation is made in Fig. 11, which shows that length increases faster than width or thickness as tuber weight increases, from one class to another. Whether the same is true of each tuber in its growth, regardless of its ultimate size, has not been determined.

In 1929, in nine lots of the Corinna strain differing as to fertilizer treatment, comparison was made between 5-, 6-, 7-, and 8-ounce tubers. In the 27 possible comparisons with an increase in tuber weight, length also increased in all instances, width in all instances, thickness in all instances, the L/W ratio in 19 instances, and the W/T ratio in 17 instances. There was an increase of the L/W ratio from the 5-ounce tubers to the 8-ounce tubers in all lots except the one receiving 5-8-14, 3000 pounds to the acre. This increase was significant in the lots receiving 0-0-7, 5-8-0, 5-8-7, 5-8-10, and 5-8-14, and not in the lots receiving 5-8-4, no fertilizer, 5-8-4 at 3000 pounds, or 5-8-14 at 3000 pounds. (The rate of application was 2000 pounds per acre except for the last three lots just mentioned.) Comparing strain differences with tuber-weight differences, the former ranged from 2 to 17 per cent in seasonal maxima for length, while 8-ounce tubers showed a 40 per cent difference over 4-ounce tubers in the same Green Mountain strain in one year. Corre-

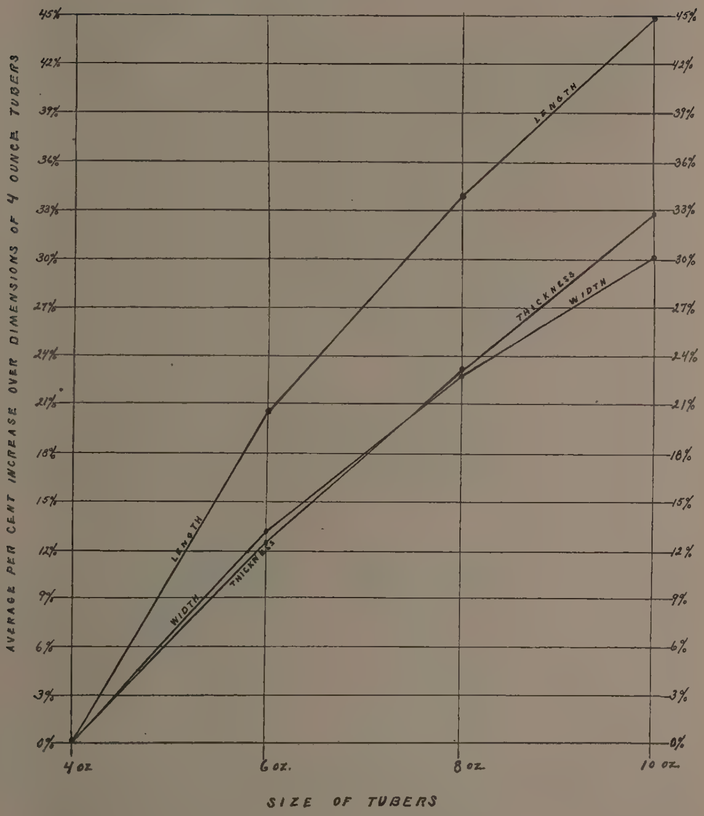

FIG. 11. Crop of 1927, comparison between 4-, 6-, 8-, and 10-ounce tubers of the same Green Mountain stock, Corinna strain, as to tuber dimensions. Note that length increases with weight faster than the other two dimensions. See Fig. 10 for effects on dimension ratios and Fig. 16 for device for measuring tuber dimensions.

sponding effects appear with reference to width and thickness. In the L/W ratio, a tuber weight difference of 4 ounces gave 8 to 16 per cent difference, compared with 1 to 9 per cent differences due to strain (Table 9, comparisons 8, 10, 13, 18, etc.). In the W/T ratio, the two conditions produced variations that were similar but less marked. Thus a variation of several ounces in tuber weight had a greater effect upon tuber dimensions and

L/W proportion than did the strain. This emphasizes the statement, made previously, that in a comparison of strains as to tuber type one should consider tuber weight as an important condition.

TABLE 9

Comparison of Various Causes of Differences in Tuber Narrowness (Ratio of Length to Width)

Comparison no.[1]	Cause of difference	Year of comparison[2]	Lots compared[3] With higher result	Lots compared[3] With lower result	Lower result	Difference as to lower result[4]
						%
1	Disease and field, etc.	1925	Spindle tuber B. & A. Green Mountains planted in standard way in field B	Healthy B. & A. Green Mountains planted in tuber units in field A	1.28	44*
2	Disease and strain	1925	Spindle tuber B. & A. Green Mountains	Healthy Corinna Green Mountains	1.31	41*
3	Disease and strain	1921 (*104*, Table V.)	Spindle tuber Green Mountains	Healthy Ball Green Mountains	1.30	38*
4	Variety	1923	Green Mountains	Bliss Triumphs	0.95	36*
5	Variety	1924	Green Mountain	Bliss Triumph (R.)	0.93	30*
6	Variety	1923	Green Mountain	Irish Cobbler	1.02	27*
7	Tuber weight	1922	Ball Green Mountain 8-oz. tubers	Ball Green Mountain, 4-oz. tubers.	1.13	17*
8	Tuber weight	1922	Ball, 8-oz.	Ball, 4-oz.	1.13	16*
9	Variety	1924	Green Mountain	Russet Rural	1.05	15*
10	Tuber weight	1923	Ball, 8-oz.	Ball, 4-oz.	1.16	14*
11	Variety	1924	Green Mountain	Irish Cobbler (B.)	1.07	13*
12	Season	——	Corinna, 1927	Corinna, 1924	1.21	12*
13	Tuber weight	1927	8-oz.	4-oz.	1.19	9
14	Strain	1923	Ball	Cunningham	1.21	9
15	Variety	1924	Green Mountain	Spaulding Rose	1.12	8*
16	Strain	1922	Ball Green Mountain	Rich Green Mountain	1.21	8*
17	Field, etc.	1925	Corinna Green Mountain planted in standard way in field B	Corinna Green Mountain planted in tuber units in field A.	1.22	8*
18	Tuber weight	1929	Corinna, 8-oz.	Corinna, 4-oz.	1.20	8*
19	Variety	1923	Green Mountain	Russet Rural	1.19	8*
20	Season	——	Cunningham, 1925	Cunningham, 1923	1.21	7*
21	Season	——	B. & A., 1925	B. & A., 1922	1.20	7*
22	Season	——	Rich, 1923	Rich, 1922	1.21	7*
23	Strain	1925	Cunningham, P. E. I.	Corinna	1.22	7
24	Fertilizer	1929	5–8–0	0–0–0	1.27	7*
25	Fertilizer	1929	5–8–14	5–8–14, 3000	1.18	7*
26	Season	——	Ball Green Mountain 1923	Ball Green Mountain 1924	1.25	6*
27	Strain	1924	Rich	Corinna	1.21	6
28	Variety	1923	Green Mountain	Spaulding Rose	1.23	5*
29	Fertilizer	1929	5–8–0	5–8–7	1.29	5*
30	Skips	1924	Corinna Green Mountain with 1-hill skips between tuber units	Corinna Green Mountain with no skips	1.21	4
31	Season	——	P. E. I., 1923, 1925	P. E. I., 1926	1.25	4
32	Fertilizer	1929	5–8–7	0–0–7	1.25	3
32A	Tuber line selection	1928	Martin choice selected Green Mountain	Martin bulk Green Mountain	1.28	3
32B	Do	1928	Martin choice selected Green Mountain	Corinna Green Mountain	1.28	3
33	Substrain	1925	Corinna Green Mountain tuber line H–26	Corinna Green Mountain	1.22	2

TABLE 9—Concluded.

Comparison no.[1]	Cause of difference	Year of comparison[2]	Lots compared[3] With higher result	Lots compared[3] With lower result	Lower result	Difference as to lower result[4]
						%
34	Disease	1925	Healthy Corinna Green Mountain	Giant-hill Corinna Green Mountain	1.28	2
35	Fertilizer	1929	0–0–0	0–0–7	1.25	2
36	Fertilizer	1929	5–8–7	0–0–0	1.27	2
37	Fertilizer	1929	5–8–7	5–8–14	1.26	2
38	Size of skips	1925	Corinna Green Mountain with 3-hill skips between tuber units	Corinna Green Mountain with 1-hill skips between tuber units	1.22	1
39	Season	——	H. & C., 1923	H. & C., 1924, 1925	1.27	1
40	Fertilizer	1929	5–8–4, 3000	5–8–4	1.28	1
41	Strain	1926	Corinna	Cunningham, B. & A., P. E. I.	1.25	1

[1]In order of decreasing difference as expressed in the last column on the right.
[2]See Literature Cited for reference, and text of this bulletin for some other data. Some data transcribed directly from records. Maximum difference for any one year, or for any one strain in reference to effect of season, given here.
[3]Lots of Green Mountain variety and on Aroostook Farm unless otherwise indicated.
[4]An asterisk (*) denotes that the difference was known to be significant.

STRAIN *VS.* VARIETY

The crops of the variety lots grown in the seed plot and rogued in 1923, were sorted by tuber weight and the 8-ounce tubers thus obtained were measured in the usual way. In order of decreasing length of tuber, the varieties ranked: Green Mountain, Spaulding Rose, Russet Rural, Irish Cobbler, and Bliss Triumph, with the Green Mountains and Bliss Triumphs significantly different from all others. The same list also is in order of increasing width, with the Green Mountains and Bliss Triumphs again significantly different from all others. The list is in order of increasing thickness except for the Russet Rurals being thinnest, and the first three were significantly different from the last two. In narrowness (L/W ratio) the results were like those for length. In W/T ratio both Russet Rurals and Spaulding Rose were ahead of the Green Mountains, and these three were significantly ahead of the other two varieties.

From the sorting by tuber weight of the variety lots grown in the seed plot in 1924, again 8-ounce tubers were obtained that were measured. The ranking was as for 1923 in length, but not in width. The ranking was like that for 1923 in thickness except for the Green Mountains and Spaulding Rose changing places. In L/W and W/T ratios the results were as for 1923.

Comparing the Green Mountains with each other variety, the length differed from 3 to 26 per cent, while Green Mountain strains differed only from 2 to 7 per cent, in any one year. Making similar comparisons in other dimension characteristics, we find for intervarietal *vs.* inter-strain differences respectively: 2 to 8 per cent *vs.* 1 to 5 per cent in width; 1 to 18 per cent *vs.* 2 to 3 per cent in thickness; 5 to 36 per cent *vs.* 1 to 9 per cent in L/W ratio (Table 9, comparisons 4, 5, etc.); 2 to 13 per cent *vs.* 0 to 5 per cent in W/T ratio. Thus differences between Green Mountain strains equalled the differences between Green Mountains and some other varieties, but were less than the greater intervarietal differences.

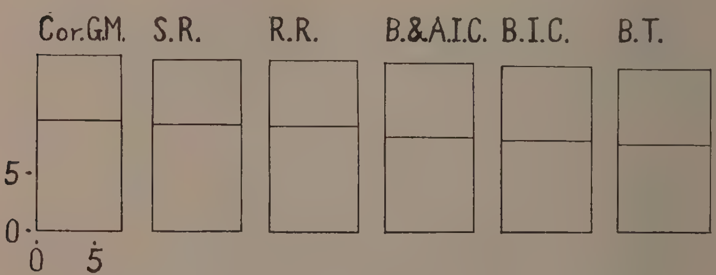

FIG. 12. Crop of 1923, several varieties compared as to tuber dimensions. The numbers indicate centimeters, 5 of which equal about two inches. In each small figure, the larger oblong at the bottom gives the dimensions (length and width) of the average tuber in face-view, while the smaller oblong at the top gives the dimensions (width and thickness) of the average tuber in end-view. See Fig. 16 for device for measuring dimensions, and Figs. 5, 13, and 14 for similar comparisons of Green Mountain strains, of diseased lots and of crops of different seasons.

Fig. 12 shows the differences between the varieties in 1924, with respect to tuber dimensions.

STRAIN *VS.* DISEASE

Results reported on spindle-tuber shape in previous publications did not take into careful account the effect of variation in tuber weight. In 1925, spindle tuber in 8-ounce Green Mountain tubers increased the length 24 per cent, decreased the width 12 to 15 per cent, decreased the thickness 3 to 5 per cent, in-

creased the L/W ratio 41 to 44 per cent (Table 9, comparisons 1, 2, etc.), and decreased the W/T ratio 10 per cent, all these increases being greater than those due to strain. At the same time, giant hill had less effect than strain on length, width, thickness, the L/W ratio (Table 9, comparison 34), and the W/T ratio, than strain had in general. Figs. 13, and 20 to 23, show the results of these measurements of type.

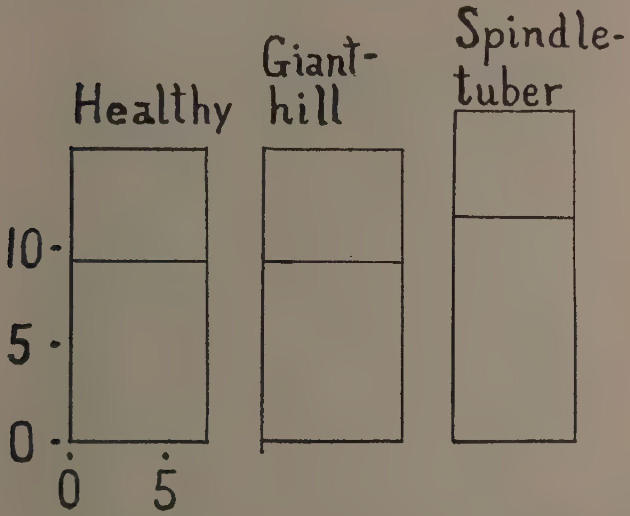

FIG. 13. Crop of 1925, Green Mountain lots with spindle tuber, giant hill, and no apparent disease, compared as to tuber dimensions. The numbers indicate centimeters, 5 of which equal about two inches. In each small figure, the larger oblong at the bottom gives the dimensions (length and width) of the average tuber in face-view, while the smaller oblong at the top gives the dimensions (width and thickness) of the average tuber in end-view. See Fig. 16 for device for measuring dimensions, and Figs. 5, 12, and 14 for similar comparisons of Green Mountain strains, of varieties, and of crops of different seasons.

STRAIN *vs.* SEASON

In 8-ounce tubers of 7 Green Mountain strains, length varied somewhat more from one season to another in one strain, than from one strain to another in the same season. This is also true

of width, thickness, L/W ratio (Table 9, comparisons 12, 13, etc.), and W/T ratio. Fig. 14 shows the dimensions of the same two strains through several seasons.

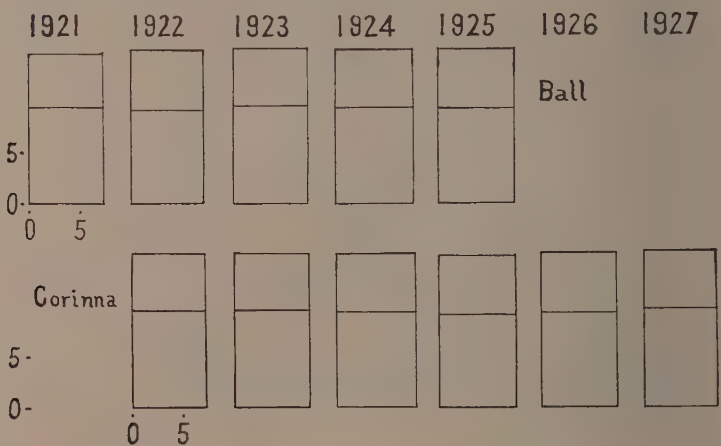

FIG. 14. Two Green Mountain strains, each with the crops of several consecutive seasons compared with each other as to tuber dimensions. The numbers indicate centimeters, 5 of which equal about two inches. In each small figure, the larger oblong at the bottom gives the dimensions (length and width) of the average tuber in face-view, while the smaller oblong at the top gives the dimensions (width and thickness) of the average tuber in end-view. See Fig. 16 for device for measuring dimensions, and Figs. 5, 12, and 13 for similar comparisons of Green Mountain strains, of varieties, and of diseased lots.

It should be repeated here that interseasonal comparisons are involved with some differences in soil, size of seed pieces, amount of fertilizer, and other factors.

STRAIN *vs.* FERTILIZER

In 1929, the Corinna Green Mountain strain as grown in 9 fertilizer plots was studied as to tuber type. Unless otherwise indicated, the amount of fertilizer applied was 2000 pounds an acre. Comparing 0-0-7 *vs.* 0-0-0 (no fertilizer), 5-8-7 *vs.* 5-8-0, 5-8-14 *vs.* 5-8-7, and 5-8-14, 3000 pounds, *vs.* 5–8–14, 2000 pounds, we find that the presence of potash, more potash, or more

fertilizer with high potash content, generally tended to decrease the length, increase the width, increase the thickness, decrease the L/W ratio, and increase the W/T ratio. On the other hand, comparing 5-8-0 *vs.* 0-0-0 (no fertilizer), 5-8-7 *vs.* 0–0–7, 5–8–7 *vs.* 0-0-0 (no fertilizer), and 5-8-4, 3000 pounds, *vs* 5-8-4, 2000 pounds, we find that the presence of nitrogen and phosphate, complete fertilizer, or more fertilizer not high in potash, generally tended to increase the length, decrease the width, increase

FIG. 15. A tuber representative of about one-third of the average-sized tubers grown with a 5-8-0 fertilizer mixture (with no potash), in Green Mountains, Corinna strain, 1929. Such tubers increased the average length and L/W ratio of 8-ounce tubers.

the thickness, increase the L/W ratio, and decrease the W/T ratio. There were significant differences in the L/W ratio in 3 of the 8 comparisons. Significance was found lacking for the other comparisons.

Fig. 15 shows a tuber representative of about one-third of the "average-sized" tubers produced with the 5-8-0 mixture. Such tuber type gives an excessive L or L/W ratio for a given weight of tuber.

The variation with these fertilizer treatments was about equal to the variation in seasonal-maximum strain differences with reference to length and W/T ratio, and was less with reference to width, thickness, and L/W ratio. (Table 9, comparisons 14, etc.) In other words, the fertilizer ratio or amount in some ways had as much effect as strain on tuber type.

STRAIN *VS.* LOCATION AND METHOD OF PLANTING

Location on a farm, location in a field, tuber-unit *vs.* normal planting, tuber-unit skips, and length of skips, had about the same effect as strain with respect to W/T ratio and had somewhat less effect than strain on length, width, thickness, and L/W ratio.

CONCLUSIONS REGARDING RELATIVE EFFECTS OF STRAIN AND OTHER CONDITIONS

The rank of strain in comparison with other conditions, as expressed in percentage change, varies with the characteristic studied.

With regard to yield rate, strain (within the conditions of our comparisons) generally ranks below several degeneration diseases, below spraying, below season, below fertilizer, within the range of variety, and like location in a field, as an influential factor.

With regard to tuber weight, strain generally ranks below season, below method of planting, below fertilizer, like variety, like selection of overweight seed tubers, like location in the field, and like certain degeneration diseases.

With regard to tuber type, strain generally ranks below tuber weight, below spindle tuber, somewhat below season, within the

range of variety, like giant hill, like location in the field, like method of planting, and somewhat above fertilizer.

In general, yield rate, tuber weight or size, and tuber type vary less from strain to strain than with a number of other conditions, and vary more only in comparison with certain intervarietal differences.

DISCUSSION OF SIMILAR TESTS MADE ELSEWHERE[13]

It seems desirable to give a brief discussion of the results of similar tests made elsewhere, which in part confirm, and in part disagree with, our results. It is impossible in all cases to distinguish here between the effects of the current environment, the effects of perpetuated diseases, the effects of past environment, and the effects of actually inherited differences arising from bud mutations or otherwise. However, an attempt will be made in the following discussion to center attention upon each of these phases in turn. This discussion also will serve to bring out the general complexity of the problem of improving potatoes by means of strain or tuber selection, contrary to the common belief that such a process is comparatively simple.

FIELD TESTS AS INFLUENCED BY THE CURRENT ENVIRONMENT

As we have shown in preceding pages, conditions of the present environment may have more effect than strain has upon yield rate, tuber weight, or tuber type. Therefore information is important that helps to show how the effect of current environmental conditions can be reduced or at least accurately measured.

With regard to yield comparisons, for general ideas and bibliography on the technique of field experiments the reader may well begin with the reports of the Committee on Standardization of Field Experiments of the American Society of Agronomy (*20*). About the most complete list of environmental factors in potato comparisons is given by Chittenden who includes

[13]The senior writer assumes sole responsibility for this part of the bulletin, except where stated otherwise.

kind of soil, manures (European term for fertilizers), climate, water supply and cultivation, source of seed, treatment of seed tubers, treatment of sprouts, method of cutting, treatment of cut seed, time of planting, and distance apart of plants (*18*, p. 46-47). We may add shape of seed pieces, spraying, time of harvesting, previous treatment of land, and depth of planting.

REPLICATIONS AND SIZE OF PLOTS

Errors due to variation in soil fertility and other localized influence are important. They are being detected in agronomic experiments by the use of replications arranged in some satisfactory fashion.

Salmon writes: "Given a certain amount of money and equipment for an experiment, extensive replication means less attention to individual plots, less care in measuring, weighing, and computing yields, greater difficulty in completing tillage operations and seeding on the same day and under similar weather conditions, and more delay in harvesting...with consequently greater opportunity for damage... With extensive replication the elimination of competition and border effect is more difficult and the opportunity is lessened for securing other data". (*97*, p. 236-7.)

There was little available information on plot technique with potatoes at the time our strain comparisons were begun in 1922. Even now, with such progress as has been made, the choice of methods may be considered still somewhat unsettled among the students of the problem. Most of the students seem to prefer from five to ten replications, hand-planted, each in single rows 17 to 100 feet long (*57; 64; 65; 68; 84; 90; 94*, p. 92-94; *95; 133*). In one instance, forty single-plant plots seem to be approved (*18*, p. 46).

As pointed out by "Student" (*122*, p. 708-709), in field experiments which are "to find out whether some change of practice is likely to benefit farmers who follow it", "as far as may be, large-scale methods of agriculture should be used". The application of this principle in our work is seen in the use of certain methods of planting and weighing that have been used by farmers, in preference to other (laboratory) methods that never would be used even by such growers as are most inclined to

follow any standardized methods of strain comparison and tuber-line selection that may be developed.

COMPETITION BETWEEN PLOTS, TUBER UNITS, AND HILLS

With regard to competition between plots, which may consist only of single rows, and between tuber units and hills, there are varied opinions. Brown in Connecticut concluded that "yields of potatoes are not influenced by competition between single row plots" (*13*, p. 258). Musgrave found in New Jersey a depression of the yield of check plots due to competition by adjoining high-yielding plots but such competition did not affect more than the first check row, indicating that one buffer row is enough (*79*; *80*; *81*).

In tuber-unit comparisons it is important to consider competition between adjacent hills and groups of hills, and to correct for missing hills in case of imperfect stand. Up to about 50 per cent of the loss in yield due to missing hills may be made up by the yields of the adjoining hills (*31*, p. 65-66; *109*, p. 3; *110*, p. 45-47). Livermore concluded that differences between tuber halves could be due to a systematic difference in cutting (*68*, p. 861). He also showed that "the effect of missing hills is markedly influenced by soil and climatic conditions. Variety and size of seed piece play a minor rôle in this respect" (*68*, p. 895).

As an extreme example of the effect of lack of competition (together with other favorable factors) we may cite a 73-pound hill, yielding 146-fold, grown in the State of Washington (*137*). (On the basis of area covered, this hill produced at the rate of only about 344 bushels an acre.)

Eustace found that variation was not materially reduced by apparently more uniform conditions under which a comparison was repeated, and concluded that "factors which are apparently unimportant produce wide differences in yield". (*29*, p. 61-62.)

For the Green Mountain strains in our tests, which strains varied little, it would seem that a single-row plot would be quite satisfactory from the standpoint of competition. In our tuber-unit comparison where units were rogued, special efforts were made to determine the proper correction factor for the particular experiments affected, as has been shown in the preceding pages.

In most of our comparisons the stands have been near enough to completeness so that corrections were not considered necessary.

TUBER SIZE AND SHAPE

Environmental conditions of the current season have been found to have effects upon tuber size and shape as well as upon the yield (*107*; *108*; *119*, p. 37).

TABLE 10

Tuber Dimensions and Dimension Ratios for Different Sources[1]

Variety	Source[2]	Year	Length Cm.	Length In.	L/W	T/L	T/W	W/T
Green Mountain	U.S.	1916	10.80	4.25	1.48	.47	.70	1.44
" "	N.Y.	——	8.91	3.51	1.37	.53	.72	1.38
" "	Maine	1922	8.80	3.46	1.20	.66	.78	1.28
" "	Maine	1923	9.33	3.67	1.24	.60	.74	1.35
" "	Maine	1924	9.48	3.73	1.25	.60	.74	1.35
" "	Maine	1925	9.45	3.72	1.28	.61	.78	1.30
Rural	U.S.	1916	9.22	3.63	1.23	.55	.68	1.47
"	N.Y.	——	8.99	3.54	1.19	.60	.71	1.41
Russet Rural	Maine	1923	9.17	3.61	1.19	.61	.72	1.38
" "	Maine	1924	8.58	3.38	1.05	.67	.70	1.44
Rose Sec. 2	N.Y.	——	7.81	3.07	1.14	.60	.69	1.46
Spaulding Rose	Maine	1923	9.25	3.64	1.23	.61	.75	1.35
" "	Maine	1924	9.02	3.55	1.12	.61	.68	1.48
Cobbler	U.S.	1916	6.99	2.75	1.13	.80	.90	1.11
"	N.Y.	——	7.94	3.13	1.03	.78	.80	1.25
Irish Cobbler	Maine	1923	7.93	3.12	1.02	.81	.82	1.22
" "	Maine	1924	8.44	3.32	1.07	.73	.78	1.29
Triumph	U.S.	1916	7.14	2.81	1.00	.80	.80	1.25
"	N.Y.	——	6.43	2.53	.98	.82	.80	1.25
Bliss Triumph	Maine	1923	7.59	2.99	.95	.87	.83	1.21
" "	Maine	1924	7.45	2.93	.96	.89	.82	1.24

[1]See also part of "General Methods" on "Measurement of Tuber Shape" in this bulletin, p. 6.
[2]From U. S. and N. Y., ideal selected tubers, according to Hardenburg (*49*, p. 322). From Maine, average 8-ounce tubers, same strain of any variety in different seasons.

It is interesting to compare tuber dimensions and dimension ratios as reported by Hardenburg (*49*) for two sets of "ideal" tubers, with those secured by us as the average for 8-ounce tubers in different seasons and varieties. This is done in Table 10. The data in this table show that in Green Mountains, with the length for the Maine stocks mostly falling between the U. S. and N. Y. lengths, still the L/W ratio is consistently lower and the T/W ratio is consistently higher for the Maine field averages than for the U. S. and N. Y. ideal averages. Either

environment alters these ratios, or chosen ideal and field norm are not in agreement. In Bliss Triumphs, with the length greater in Maine, still the L/W ratio is less.

In Germany, Neumann (*85*) determined the length, width, and thickness of tubers in relation to various conditions. In the same stock, length of tuber increased with weight (p. 37) and the L/W ratio was greater as the length increased (p. 7). Tubers lengthened chiefly through growth in the region lying directly under the bud end (p. 12). Tuber size reached its maximum when the leaves began to lose their color (p. 14). It is claimed that nitrogenous fertilizer postponed tuber growth and plant maturity, and increased the L/W ratio from about 1.15 to 1.33, and that this effect was consistent and independent of the increase in tuber size (p. 13-15). However, the ratios for individual tubers were not determined, and if they had been, the differences might not have been significant, judging from the probable errors given for the determined means. Apparently no correction was made for the effect of tuber weight or size upon dimension ratios. Progressively later diggings in the same series of plants did not increase the L/W ratio significantly (p. 15). The lengthening effect of nitrogenous fertilizer was absent in sand at high soil-moisture content (p. 19). Thickening, giving a more nearly cylindrical form, resulting from potash and phosphoric-acid fertilizers, and from an increase in soil water, is admitted to be slight and not outside experimental error (p. 20-21). The author admits that the 6 pots in a series were too few, and suggests that the great effect of fertilizer and the variation of its effect with variation in soil water, require the absence of fertilizer in a study of soil type and soil water (p. 22). Closer spacing of plants reduced tuber weight, each dimension, and the L/W ratio, but not the T/W or W/T ratios (p. 22-25). In general the study indicates that tuber form is influenced by several environmental factors, but that proof of such influence requires improvements in technique over that used in the study.

In Germany, Müller and Braun (*76*) have recently reported results secured with methods similar to ours, using a sliding caliper to measure tuber dimensions. They concluded that dimension ratios should be determined for each tuber, that leafroll and similar diseases can affect tuber form, and that dimension ratios vary with tuber weight (p. 4-6, 13 footnote 5, 24, 32, 37, 39, and

40). In a study of tuber dimensions at different dates of harvesting, with tubers included down to less than 5 mm. (1/5 inch) in length, and with the average length reaching a maximum of only 37.4 mm. (about 1.5 inches), dimension ratios were determined that when converted by us show a tendency of the L/W ratio to increase from 1.12 to 1.27 between July 11 and August 12 in one variety, and from 0.97 to 1.11 between August 12 and September 21 in another variety (p. 6, Tables 1, 4, and 5, Figs. 2 and 4). Origin-strains of a variety differ significantly in tuber dimension-ratios even when grown in the same field; environment influences tuber form even to the second generation; and selection for differences in tuber thickness can be made with no effects apparent in the progeny (p. 28, 30-32, 39, 40, and 41).

The variability of tuber form has been studied in Germany also by Schwartz, who concluded that in general the form of the tuber is influenced by environmental conditions (*106*). He noted, of special interest here, a lengthening with increase of tuber weight and with increase of humus content of the soil, a shortening by K_2O that is hindered by N and P_2O_5, and a thickening by N.

CONCLUSION ON CURRENT ENVIRONMENTAL INFLUENCE

These accounts show that much care is needed to prove in any field test that there is a real or significant difference and that it is due to a certain factor or condition, either of the current season or of past seasons. This should be borne in mind when the following sections are read.

Apparently Inherited Differences Due, or Probably Due, to Perpetuated Diseases

In strain comparisons, diseases may induce considerable error. Bacterial and fungous diseases are mostly obvious and so can mostly be eliminated by inspection of tubers and vines. Some of them, however, and most of the viroses (degeneration diseases or virus diseases) cannot be so eliminated and may be apparently inherited due to being perpetuated through the tubers, though of course they are not inherited in the strict or genetic sense. Degeneration, formerly ascribed to varietal senility, is now consider-

ed as being largely due to viroses (*66*, p. 948; *94*, p. 14). Some of the viroses are obvious in the growing plant while others are more or less masked. There is abundant evidence of modification or masking of symptoms due to varietal, climatic, and growth-stage factors (*40*, p. 3-4; *42*; *43*; *54*; *55*, p. 70; *77*, p. 33-34; *78*, p. 182; *104*, p. 99-101; *124*; *130*). Furthermore, for all practical purposes varietal masking may be complete in some instances, being disclosed only by transmission of the masked disease to other varieties or species of plants (*5*, p. 177; *54*; *100*).

Parts of a strain may become different due to local or regional differences in spread of viroses (*39*, p. 59, 91-92; *102*, p. 522-525, 528).

Differences between strains of Russet Rurals not due to recognizable disease, disclosed in Ohio (*16*, p. 61; *88*, p. 49), may easily be due to mild mosaic or leafrolling mosaic. Both of these mosaics have been transmitted in Maine from Green Mountains to Russet Rurals (of a Michigan strain, like those tested in Ohio), and back to Green Mountains, but with symptoms not apparent on the Russet Rurals except upon close comparison with uninoculated controls and for only several days at one time during the season.[14] In addition, in Ohio climatic masking probably would be more pronounced than in Maine due to the higher prevailing temperatures (*42*; *43*; *53*; *124*, p. 606).

Hardenburg reported in 1922 that "high temperatures tend to produce devitalization", giving an illustration that shows leafroll symptoms in the devitalized seed (*46*, p. 1157-1158). We have since learned that leafroll spreads rapidly on Long Island (*102*, p. 522-525) where his illustration was taken.

Myers of New York points out the difficulty caused by diseases, and reports having isolated four lines that were "sufficiently different from the parent stock to be classified as a separate variety". He proceeds by saying that "such striking mutations are comparatively infrequent but smaller changes seem to occur with greater frequency", so that "the writer has no difficulty in experimentally demonstrating that an ordinary variety of potatoes may be separated into a number of definite, distinct strains which differ with respect to slight morphological characteristics

[14]From unpublished observations on the second-generation plants of inoculations described by Schultz and Folsom *(102)*.

and productivity". (*83*, p. 110-111.) The same writer in a later paper further points out that "it is desirable to handle as large a number of individuals as possible, since the chance of obtaining diverse strains varies directly with the number of initial selections that are made" (*82*, p. 7-8). The writer mentions mosaic and leafroll as causes of error in selection, but apparently is not aware that several kinds of mosaic and other kinds of degeneration diseases may be present and be causes of error through not being recognized or through varietal and environmental masking of symptoms. (See the previous paragraphs of this section of this bulletin.)

A similar article by an associate of Myers may be mentioned, with the remark that results with odds running from 4:1 up to 131:1, odds of 30:1 being considered significant, are considered to be "quite consistent" (*69*, p. 425).

A method more recently developed at Cornell involves the comparison of 500 tuber units planted with similar tubers from as many high-yielding hills, the selection of 50 or 60 of these by observation, a further cut the next year to 20 by means of yield data, and further reductions year by year. Throughout these years, roguing of disease and isolation of tuber lines are said to be among the conditions essential for success. Following this method, Livermore has secured tuber lines that were free of recognizable disease and yet yielded as much as 30 per cent more than the original stock in some instances (*70*). This was done in New York, where some degeneration diseases are commonly masked, especially in some of the more common varieties. However, regardless of that, consistent superiority for several years is a result worth while.

Maturity is supposed by some to affect the seed value. Immaturity is said to be correlated with high nitrogen, and region of origin with nitrogen and starch content, independently (*94*, p. 103 and 105). However, Appleman and Miller report that "the ripening and maturing processes in potatoes may continue during storage, so that by the end of the rest period immature potatoes large enough for seed have practically the same percentage composition and respiratory response as potatoes allowed to mature on the vine if both are stored under the same conditions. The data in this paper do not reveal any chemical or physiological basis for the superiority of immature potatoes for seed. The

cases reported of immature seed giving better results than mature seed may have been due to greater freedom from degeneration diseases in the immature seed." (*2*, p. 577.)

In Holland, Botjes found that with exposure to infection by degeneration diseases which were present in the immediate environment, immaturity of tubers, resulting from earlier digging, gave less of such diseases in the progeny. On the other hand, with healthy surroundings such immaturity gave no difference in disease in the progeny. (*12*.) Thus through differences in exposure to disease, immaturity of seed tubers might have varying effects on the yield of the progeny.

In New Jersey, Martin reports: "Freedom from disease alone is not sufficient, however, to insure tubers of highest vigor. The question of maturity is one of considerable importance, since it has been frequently demonstrated that immature tubers possess more vitality than mature tubers and consequently are more desirable for seed purposes.... From the results of the studies here presented it is apparent that the more immature the seed the greater will be the yield of marketable potatoes". (*75*, p. 456, 460.) We would point out, however, that this report was written before it was known that spindle tuber and leafrolling mosaic, at least, were common in Irish Cobblers (*102*), the variety being tested in New Jersey, and that these diseases might easily spread more as the season progressed, so that the greater maturity might be bound up with greater spread of virus diseases.

In Connecticut in Green Mountains, Irish Cobblers, and Russet Rurals, home-grown strains when rogued of disease, but yet showing slightly more disease than certified stocks from other states, yielded more than the imported certified stocks. Digging at later dates gave progressively higher degeneration-disease counts and lower yielding power as results apparent the next year. (*21*, p. 5-6.)

In Virginia "three tuber-unit selections of the V. P. I. Green Mountain have proved to be superior to the parental strain as shown in Table 22" (*125*, p. 85). This table shows differences of 25 to 40 per cent in the 4-year average yields. However, in two out of twelve comparisons the parental strain yields more. While we agree with Sachs (*93*) that it is sometimes more important to know "an average over a period of years" rather than the consistency of differences, it seems desirable to test the Vir-

ginia comparisons by Student's method (*71*; *72*). (In our use of the available figures, they were converted to the nearest whole numbers and for 1926 the average of the two parent-strain yields was used.) Our results with Student's method give odds of only 10.0, 12.1, and 34.5 respectively for the three tuber lines being superior, whereas odds of 30 are considered as being hardly significant in such instances having only four pairings. Even here, our experience shows that mosaic may be masked in Virginia (*102*, p. 522) so that any significant difference from selection may be due to difference in degeneration-disease content. This explanation seems still more probable in case of the Bliss Triumphs referred to in the same report, with one strain showing something like a 200-per cent increase over the parent stock.

Reports from Missouri of Irish Cobbler, Early Ohio, and Bliss Triumph strains differing widely although "all of the strains were practically identical in appearance and true to the varietal type", show that "weak or diseased strains are far more numerous than strong strains" (*92*, p. 5).

In Iowa, Fitch finds that "a series of hot seasons quickly ruins the producing power of any lot of seed forever" (*30*, p. 299) and that soil type and type of planting determine seed vigor. However, as he suggests, proof requires controlled pot experiments. He also relates that proximity to earlier varieties results in injury, which could be explained by our results with the spread of rugose mosaic to adjacent healthy stocks (*102*, Fig. 1 and p. 518, 521), and suggests that a virosis may be concerned (*30*).

Gillig believes that "in certain tubers there is a dominant power or tendency that holds and fixes, to a very great extent, the type of tubers grown from them" (*41*, p. 156). However, he admits the important effect of disease, soil, and isolation in the region where he worked, which was the Red River Valley of North Dakota and Minnesota, and he gives no data showing that these effects were all eliminated or that quantitative measurements confirmed his belief.

Whipple in Montana has found a correlation between tuber type and the presence of degeneration diseases (*134*). Judging from our experience and his data, the smoother tuber outline found by him to be associated with degeneration of certain kinds, probably is due to earlier maturity of the tubers resulting from degeneration diseases.

As brought out by Sax and Gowen (*99*, p. 189), further results reported by Whipple (*135*) are to be interpreted thus: "The clonal variety of Green Mountains was rather variable and ...variations in yield were relatively permanent because of the presence of diseased lines. In the Rural New Yorkers, little affected by disease, we find practically no permanence of variations in performance".

Stewart and Tingey review the work of various others on hill selection, but apparently regard their own pronounced success in Utah as being due "at least partly (and probably largely)" to the elimination of hills affected with degeneration diseases (*113*, p. 28).

Sandsten and Tompkins in Colorado concluded that "under favorable conditions...ill-shaped, knotty tubers derived from good stock, will result in a normal tuber development and yield" (*98*, p. 13). They also report that "different types of soil and climate exert a tremendous influence on vegetative parts of the plants during the growing season" (*98*, p. 13). They conclude that "degeneration, or the so-called 'running-out' of varieties in Colorado potatoes is caused primarily by lack of proper seed selection, or none at all", so "that a high yield cannot be maintained season after season when no attention is given to seed selection" (*98*, p. 13). The illustrations suggest that tuber selection might be upholding yield rates through reducing spindle tuber. Spindle-tuber Green Mountains were selected in Maine and were kindly grown in Colorado by Sandsten and Tompkins. Samples of the progeny returned to Maine, while showing less conspicuous symptoms than the parent tubers—a common occurrence—still were all obviously spindle-tuber. When they were marked and mixed among healthy tubers with the marks hidden, and the mixture was shown to students of the disease, the diseased tubers were selected from the mixture without trouble or error. The opinion held in Colorado that these had "recovered" due to the climate, indicates that spindle tuber was unrecognized as such, and probably was affecting results, there.

A change in eye type reported by East evidently was due to the spindle-tuber disease (*27*, p. 136, Pl. II, c).

Salaman has described a color-loss mutation showing also a lessened cropping capacity, narrower leaflets, and a greater L/W ratio, (*96*, p. 277, 279, 283), but it seems possible that outside

of color loss the changes described might be due to the spindle-tuber disease. Even color can be changed somewhat by spindle tuber (*33*, p. 29-30).

Small tubers taken from the top of a plant of the variety White Prizetaker in Alaska served as the origin of a strain superior to the parent (*1*, p. 5), but the question arises as to whether or not the aerial tubers were a symptom of the Rhizoctonia disease (*R. Solani* Kühn or *Corticium vagum* B. & C.) and whether or not their use resulted in superiority through eliminating the sclerotia of the pathogen.

The preceding instances bear on benefits of selection probably or possibly being due to disease reduction. In passing it may be noted that even the elimination of diseases is not always a result to be gained from selection, as sometimes diseases spread fast enough to eliminate the advantages of selection. As examples of this we have reports from Minnesota (*62*; *126*), Indiana (*40*, p. 20), New York (*70*, p. 42), and Rhode Island (*132*, p. 762, 779-780).

Results reported recently from Rhode Island, of immaturity making the yield 10 per cent greater through increasing the number of eyes to a seed piece, and of potassium and other fertilizer elements affecting the seed value, were from the test just mentioned as being involved with degeneration diseases.

Other recent reports of the existence of strain differences have been made with the disease factor thought or intended to be eliminated but not proven to be eliminated, in our opinion (*50*; *120*, p. 206).

A number of accounts are not mentioned here in which it is not clear whether the reported differences probably were due to perpetuated diseases, past environment, or some truly inherited quality.

Stuart sums up the situation well, as follows: "To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures". (*116*, p. 6.)

Apparently Inherited Effects of Past Environment

Apart from the disease and genetic factors considered elsewhere, there may possibly be apparently inherited effects of environment. That is, environmental factors may perhaps have direct effects that persist in the tubers and become apparent the next year. In comparing samples of various strains one would expect such effects to be more important the first year than in succeeding years.

Soil influences tuber shape (*33*; *48*; *94*, p. 136) which in practice often influences the size of seed piece and so indirectly affects the yield rate.

Hardenburg suspects that "the influence of soil type, per se, in respect to vigor and tuber-set in the seed crop may be transmitted to the following crop" (*47*, p. 100).

Krantz and Tolaas report that "it was found that environmental differences, in so far as they were indicated by the yield the grower obtained, by nitrogen and dry matter content and by the tuber form of the seed, did not influence the yield" (*63*, p. 46).

Chittenden states that in England, seed stocks "from peat-bottom land give better yields than those grown in the sandy loam a few yards away" (*18*, p. 47).

Martin *et al.* state that "high and low yielding strains may be obtained from any seed producing region" (*74*, p. 23). They then show that starting with parts of the same strain and adopting the necessary measures for the elimination and control of diseases, "in four tests conducted in 1923, 1924 and 1925 in Maine with the Green Mountain variety the average yield of the Maine grown seed was 309.9 and of the New Jersey seed 310 bushels" (*74*, p. 31).

In Nova Scotia a seed stock of the Garnet Chili variety was divided. Parts were planted in northern Ontario and part was kept in Nova Scotia and planted there, for two seasons in each place. The two years in northern Ontario had no effect, inasmuch as upon the return of the stock to Nova Scotia the yield for the next two years was 263 bushels an acre as against 262 bushels for the part remaining in Nova Scotia. (*45*, p. 206-207.)

Stuart and Lombard found that storage temperatures of 32°, 36°, and 40° F. did not affect the vitality perceptibly (*121*).

Stuart *et al.* found that "mature seed obtained by early planting contained less disease than was found in the stock from either the medium or late planting" (*118*, p. 16) and that mature stock obtained by digging at the normal time contained more disease than corresponding immature stocks dug early (*118*, p. 19). In either instance the relative yields varied with the season, the amount of disease was probably too small to affect the yield, and immature seed was somewhat more productive.

In New Hampshire in 1924, tubers were dug from nearly healthy Green Mountains at different times after planting. These lots in 1925 were again nearly healthy with the maximum yield given by the 100-day stock. (*87*, p. 11-12.) However, in 1923 in a similar test, presumably also with healthy stock, the 100-day stock yielded the least (*86*, p. 16). A comparison of the two years' results in bushels per acre, follows:

Years of test	90-day stock	100-day	110-day	123- or 124-day	148-day
1922-23	363	344	359	366	
1924-25	221	353		305	256

Therefore with all samplings healthy, degree of maturity had no consistent effect.

In Maine in 1926, yields of Green Mountain potatoes did not show any effect from spraying the parent plants in 1925 with Bordeaux mixture (*10*, p. 123).

Profeit and Findlay, in England, planted seed of each of five varieties partly on heavily fertilized land and partly on unfertilized land in the same field. The respective crops were about as 2 to 1 per unit area. Tubers of the same size from the two parts of the field, in each variety, were grown in the following year in alternate rows with all conditions made as uniform as possible. In any variety the previous season's treatment failed to affect the crop more than 8 per cent, and for the five varieties the average was slightly in favor of the seed from the unfertilized part of the field. On the other hand, stocks of several varieties when freshly introduced were less productive than in subsequent years, in comparison with native stocks, "due simply to some temporary weakening in the vitality of the potatoes owing to the warmer and drier conditions under which they had previously been grown" (*91*, p. 60).

Werner has reviewed the problem of the relation of environmental factors to the productiveness of seed potatoes (*128*; *129*). He concluded that "no instance has been found reporting unquestionable evidence of any environmental effect on seed in the absence of disease" (*128*, p. 60), referring here to effect of environment during the growing season in which the seed tubers were produced. He describes experiments where a test was made of the productiveness of tubers grown under controlled conditions, including some which produced a pseudo-spindle-tuber, the results being negative as to any differential effect.

Werner found that in Nebraska when spindle tuber was present in a stock, the spread of the disease and consequent reduction of the yield the next year, were "very much greater in: (a) irrigation fields than in dry land fields; (b) eastern and central Nebraska than in western Nebraska; (c) early planted than in late planted stocks; (d) late harvested than in early harvested stocks, and (e) cultivated than in straw mulched stocks. When healthy stocks that were practically free from disease were planted, good seed stocks of apparently equal productivity were produced under all the conditions mentioned". (*127*, p. 10-11.) "All these conditions exerted a very distinct effect upon the yield and shape of the tubers during the current season, but when these tubers were planted under comparable conditions the following season they were all of about equal productivity" (*127*, p. 13).

Werner found that "the prolonging of plant life due to low temperature, high moisture, or rich soils may indirectly exert a considerable influence upon potato seed stocks (1) by extending the time the plants are exposed to virus-disease infection and (2) by allowing the tubers a shorter rest period than may be advisable". He found that controlled differences in soil temperature, soil mosture, and soil texture often had a pronounced effect upon the appearance of the tubers produced, but had no significant effect upon the productivity of these tubers in the following season in the field. (*131*, p. 410.)

In conclusion regarding tests of the effects of past environment, some results show that such effects are lacking if the disease content is the same, and most of the other results are inconsistent or are additional instances of disease content being a determining factor.

BUD MUTATIONS AND SELECTION

Although somatic mutations or bud mutations are considered to be rare, at least when concerned with certain characteristics (*94*, p. 19-25, 163), there is no real information as to how often they occur in regard to yield and tuber shape. As East says, regarding potato bud mutations, "it is very possible that with strict search, they might be shown to occur much oftener than is expected" (*26*, p. 417). He has suggested this possibility with reference to inherent yielding ability, but thought the evidence too meager and the reported successes too rare to justify recommendation of the method to commercial growers (*27*, p. 131-132, 139). Krantz believes that in clonal selection "mutations occur in the potato but are too infrequent to be of any value to the potato breeder as a means of securing better varieties", and, in fact, "that methods of potato breeding based on clonal selection have been of relatively little importance in the improvement of the potato" (*60*, p. 42). (See also *66*, p. 958.)

Dorst claims to have collected 53 potato bud mutations. One kind, the "males" or "bolters" appear the same as our "giant hills". (*25*, Fig. 13, p. 115-116.) He goes on to say: "The observed budmutations cause, particularly, alterations in color and in the development of the foliage. Such alterations are the ones most easily discerned. On the other hand, bud-mutants causing a change in yield, taste or percentage of starch etc. are, in the midst of other plants, very easily overlooked. Owing to the more rigid selection, practised in recent years in the Netherlands, strains have been found within certain varieties, which differ very considerably from each other; probably these have arisen by bud-mutation. . . .There is no good reason to believe that bud-mutation is limited to a few characteristics only" (*25*, p. 116-117).

Some potato bud mutations are of a reversing type (*32*; *94*, p. 21, 23).

Costantin in 1924 gave a summary of the literature with bibliography (*22*). It may be suggested, in view of his statements regarding the origin of some mutations from proximity to plants of the American Wonder variety, from grafting, and from the transmission of variegation (*22*, p. xxvi, xxvii, xxxiv, xxxv (1), xxxviii), that the effects of mutation were not clearly dis-

tinguished from the effects of degeneration diseases. Even instances of tubers of two colors being attached to the same stem, as described in his review, could be due to spindle tuber, which can change tuber color and which can visibly affect part of the progeny of a shoot (*33*, p. 29-30; *38*, p. 25 and Fig. 5; *104*, p. 55, p. 80, and Pl. 9, B, 2).

Several kinds of bud mutations have been described recently by Clark (*19*).

Several kinds of bud mutations, some occurring in single-tuber clones, have been described recently by Kotila (*59*).

Asseyeva states, apparently as part of a literature review, that bud mutations affecting productivity of the potato have been observed (*4*, p. 21). However, no reference is given, and it is remarked that such a character is of little use for the study of mutations due to its being strongly influenced by environmental conditions, so that this kind of mutation was apparently not studied by Asseyeva. Therefore the evidence is not convincing. Asseyeva concluded that "all investigated bud mutations are of the character of periclinal chimaeras, *i.e.*, only the outer cell layers are modified" (*4*, p. 24). Numerous bud mutations having to do with abnormal leaves, skin colors and chlorophyl deficiencies have been secured and propagated at the Maine Station (by Folsom, Owen, and Bonde). In certain instances the periclinal nature described by Asseyeva has been very strikingly confirmed (by Owen). A more complete report on this work will probably be given at a future date.

Without the cause being explained, certain physiological genetic differences are reported as a result of a longer period of propagation of a variety. These are better cooking quality as dependent on higher starch content (*94*, p. 33, 118) and greater susceptibility to late blight (due to *Phytophthora infestans* de By.) (*94*, p. 8, 117, 118). It would be no more surprising to find other kinds of physiological differences also developing. Any or all of these may have arisen from different times of origin of synonymous seedlings, even if these originated similarly. The cause of such differences might also be due not directly to the age of the variety, but indirectly owing to the appearance and increase of bud mutations with the passage of time.

Bud mutations may possibly occur as to susceptibility to a masked disease, as reported for susceptibility to the wart disease

(*Synchytrium endobioticum* (Schilb.) Perc.) (*11*, p. 43-44). "Indications have been found that susceptibility to leaf-roll and late blight may suddenly change. For the question of degeneration, further investigation concerning this point is very desirable" (*25*, p. 117).

Edmundson has claimed that stocks from different regions, or even from the same locality, may differ greatly in yielding power and other qualities with no disease recognized (*28*). The reported data indicate that there was practically no replication of plots, and no certainty that the differences were due to inherent differences rather than to environmental or pathological factors.

A review of the literature on clonal selection in general, previous to 1916, has been made by Dorsey (*24*), and on clonal selection in potato, by East in 1908 (*26*, p. 403-409), by Stuart in 1915 (*115*, p. 22-27), by Krantz in 1923 (*66*), and by Stewart and Tingey in 1927 (*113*). Krantz concludes that "Johansen's pure line theory can be applied to the asexual progeny of a potato seedling. There is no published experimental evidence to the contrary. To the plant breeder, as a rule, selection in such pure lines is of no practical value. The large amount of clonal selection work on the potato has made no appreciable improvement in our potato varieties. This appears to be strong evidence that the method of clonal selection does not offer reasonable hope for the further improvement of potato varieties. The present evidence does not support the conclusion that numerous strains, as represented by seed stocks of different growers, exist within the variety". (*67*, p. 28-29.) He presents experimental evidence of his own to bear out his conclusion (*60*; *63*; *66*; *67*) and thinks that inadequate attention to soil heterogeneity as well as to degeneration diseases and environmental factors, especially storage conditions, is responsible for the different convictions of some others (*67*, p. 29).

Profeit and Findlay in England pursued selection from originally healthy, large, heavy-cropping plants and small plants respectively of the same stock. Selection of seed from both the largest plants as well as from the smallest was continued in the following seasons. After five years of such selection, the average crops from the heavy and from the light plants showed no significant difference whatever. Selection had signally failed to

affect the crop. (*91*.) Similar negative results were obtained from five years' continual selection of seed tubers of different sizes, in three varieties. Each year the seed tubers of a given size were taken from that part of the stock originating, in the first year of the test, from seed tubers of the same size. Therefore results should have been cumulative if tuber size had had any effect upon yield. The conclusions were reached that "if a potato variety is kept pure and free from disease, and is grown under suitable soil and climatic conditions, there need be no deterioration", and that "selection inside the variety itself can effect no improvement as regards yield, quality or disease-resisting powers" (*91*, p. 63).

In South Dakota, seed tubers averaging 5.7 ounces were quartered when planted and compared with tubers averaging 3.1 ounces, mostly quartered. In the progeny, the two lots gave the same mode in tuber weight, 4 ounces, and the average tuber weight was determined as 4.01 and 4.06 ounces respectively. (*51*.) When the tabulation of tuber weights by ounces in this South Dakota report (*51*, p. 26 and 28) is used for the determination of a mean with a probable error, we find such to be $4.28 \pm .052$ for the product of small seed and $4.27 \pm .054$ for the product of large seed. The difference obviously has no significance. Treating the tabulation by half-ounces (*51*, p. 29 and 30) similarly, we find the respective means to be $4.01 \pm .057$ ounces and $4.12 \pm .058$. (The second mean is larger than stated in the original report because of the correction of an obvious error in total weight of 2.5-ounce tubers.) Since the difference between the means, of .11 ounce, is more than covered by the combined probable errors, obviously the difference is decidedly not significant.

The results of another test made in South Dakota were interpreted as showing that "not only is the type of tubers produced from selected seed larger than from 'culls', but also the average weight of tubers produced is greater" (*52*, p. 111). However, our analysis of the yield comparisons (*52*, table I) by means of Student's method (*71*; *72*) gives odds of only 5.88 to 1, which would leave the claim unproved. Further, in tuber weight only "2.6 per cent more tubers from selected seed are of useable size, than of those from culls" (*52*, p. 110), which as evidence does not seem convincing to us.

Stuart *et al.* found that seed pieces from oversized tubers were as productive as seed pieces from normal-sized tubers, in Green Mountains at Presque Isle, in a three-year test in 1922-1924 (*118*, p. 9-10).

Stuart *et al.* found that the selection of apical *vs.* basal Green Mountain seed pieces, gave greater yields with the former at 1.5 and 2 ounces to the seed piece. A difference of this kind is generally greater as the average weight of the seed pieces is greater. (*118*, p. 7.)

In tests reported by Stewart in New York, in the absence of serious degeneration diseases, uncut small tubers were as good as seed pieces of equal weight from large tubers with respect to yield and tuber size. Stewart also found that "subsequent conditions being equal, plants making rapid growth early in the season will outyield plants which grow more slowly". (*112*, p. 27.)

Wolfe working with the Green Mountain variety found a high positive correlation between the yield and the number of tubers, and also between the length of tuber and number of eyes, weight, and volume, but found no character of the seed tuber to be indicative of the yield (*136*).

In England, Chittenden reports failure in Up-to-Date to maintain tuber type by selecting tubers, and to raise the yield by selecting heavy-cropping plants (*18*, p. 45). His opinion of the determining factors has been given. (p. 69-70).

At Fredericton, N. B., about 80 miles distant from where our tests were carried on, a study of type in Green Mountains showed that there was little if any change due to selecting seed tubers with various shapes such as typical oblong, perfect, fair, round, with pointed seed end, with pointed stem end, round oblong with rose on end, round oblong with rose on side, strawberry type, bull nose cylindrical, and wasp waisted, even when continued for two years. (*6*, p. 41; *7*, p. 31-32; *44*, p. 29.)

In Nova Scotia the persistent selection of Garnet Chili tubers of ideal shape in three commercial stocks, was accompanied by no improvement in type. In one stock the percentage of tubers of ideal type changed from 22 to 56 per cent in succeeding seasons, only to drop the next season to 26 per cent. (*45*, p. 207-208.) This stock was grown in heavier soil than the other two and for the five years averaged 38 per cent of ideal type.

The others averaged 45 and 48 per cent, the higher being grown on soil with more humus than the other. In general, season seemed to cause more variation than location.

Stuart probably sums up the present status of the tuber-type problem best, as follows: "Most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes". (*116*, p. 13.)

Stuart's statement regarding selection has been given in a previous section of this bulletin (p. 80).

Kotila and Coons found that in various selected tuber lines there was no inherent resistance to virus diseases when exposed to them, but that in each line when kept well isolated there is great uniformity of plant type and almost total freedom from virus diseases recognizable in Michigan (*58*).

Apparent vigor is often taken as an indication of tuber production. However, Salaman finds that while "the total quantity of tuber material formed by any given plant is largely determined by the vigour of that plant", "there is probably no relationship between the genetic factors for cropping and such others as may conduce towards the production of vigour" (*94*, p. 71-72).

In the light of recent work by Krantz (*61*; *67*) and of the preceding review, it seems that selection in self-fertilized lines, by plant breeders, will yield results more rapidly and dependably than selection of tuber lines by plant breeders or by growers.

CONCLUSIONS FROM REVIEW OF TESTS MADE ELSEWHERE

The analysis of results reported from elsewhere, shows first that there is an increase in the appreciation of the difficulty of proving that one factor or condition has a certain effect upon potato yield or tuber type. This is true of factors of either the current season or the past. Often the most important factor of the past is—or may be, as far as is known—infection by perpetuated diseases, especially by those of the degeneration type. Some

tests show that differences in the past have no effect, if disease content is the same. Bud mutations are thought by some to occur with respect to yielding power and tuber type but have not been proved to occur. Tuber selection of various kinds has no proved effect except as it involves diseases or conditions that essentially are part of the current season's environment. Finally, it seems probable that, in comparison with tests made elsewhere, this series of tests in Aroostook County has had certain advantages in known freedom from degeneration diseases, at least of the types severe enough to affect yield and tuber shape, and in the use of certain exact, impersonal methods not generally employed in such studies.

GENERAL PRACTICAL CONCLUSIONS

The results of our comparisons of apparently healthy strains of potatoes have been presented under three general heads—comparison of commercial strains, comparison of tuber lines selected within a commercial strain, and comparison of strain *vs.* other conditions as a cause of differences. Briefly, the general practical conclusions derived from our comparisons were as follows. With respect to yield rate, tuber weight or size, and tuber type, commercial strains were significantly different in some instances. However, their relative rank was not consistent from one year to another. Further, strain differences were generally smaller than differences due to other conditions such as degeneration diseases, fungicides, season, fertilizer, variety, and method of planting, and were no greater than differences due to conditions such as location in the field and selection of over-weight seed tubers. With respect to yield rate, the selection of high- *vs.* low-yielding tuber units had no significant effect the next year, and very little effect in the second year. Similarly, tuber selection for type gave practically useless results. Consequently we conclude that, under the conditions of our comparisons, one healthy commercial strain is not to be preferred to another and tuber-unit selection is not to be recommended, at least in commercial practice.

Theoretically we admit that similar comparisons made elsewhere, or in this region in the future, may yield more distinct and continued differences. It seems possible that there may arise,

from the environments of the preceding season, differences which will make some strains preferable to others at least during the first season in this region. Or there may possibly arise, from apparently spontaneous mutations, strains or tuber lines that are inherently superior to others. However, our results show that without careful work and special methods, error will arise through the effects of environmental factors operating during the comparisons. In the light of our experience, we would be inclined to attribute even such apparently significant strain differences as we did obtain, possibly to unsuspected environmental differences that our methods did not disclose. Further, we think that strain differences proved by others in the past may mostly, or entirely, have been due to the carrying of masked degeneration diseases by the inferior strains. It may be claimed that from a practical standpoint it makes no difference what causes such a difference as long as one is found. While this may be true, especially if the strains are to be grown only one year, on the other hand the spread of disease might easily change the relative rank of strains if they are grown for more than a year close together.

Whatever one's opinion may be regarding the causes of such differences as have been found in potatoes between commercial strains and between tuber lines, it must be admitted that the problem of comparing strains and lines is much more complicated than it was once thought to be. An adequate study of the problem in any region requires the knowledge and use of modern plot technique, of apparatus for controlling environmental factors, and of methods of diagnosing virus (or degeneration) diseases.

Finally, any grower or manager of a seed-source test who wishes to demonstrate a difference in yield between two strains, in order to be convincing should at least choose a field with soil apparently uniform, and should alternate the two strains in two-row strips, fertilize and cultivate both the same, and weigh the yield of at least five strips of each strain. The same strain then should be superior to the other in each pair. In order for the grower to convince himself or others also regarding tuber type, the crops of at least three strips of each strain should be sorted to some extent for size, and similar-sized tubers should be carefully compared as to outline of face, general shape, bumpiness on surface, relative length, width and thickness, and other characteristics. In order to prove that a difference lasts beyond the first

season after the introduction of the two compared strains, similar seed tubers should be selected, stored in the same place, and cut similarly the following year when the comparison is repeated.

SUMMARY

(1) Comparisons of apparently healthy commercial strains of potatoes gave results of which the following are the most important.

(a) Seven Green Mountan strains, from New York, Vermont, New Brunswick, and Prince Edward Island, were compared in Aroostook County, Maine, in the five seasons 1922-1926. Between these strains there were differences in known origin, probable differences in seedling origin, and differences in seed treatment and other cultural factors in some seasons. Study was made of yield rate, tuber weight, tuber shape, and tuber dimensions and dimension-ratios. In some instances there were significant differences between strains. Nevertheless, these strains were enough alike, on the basis of the characteristics studied, to make preference of any one of them impractical.

(b) One strain of the preceding group, originally with seed tubers larger than those of the others, returned the crop with the most oversize tubers. This strain, with small seed tubers planted the next season, then repeated the performance. In the third year, selection of oversize tubers in this strain returned a significantly greater average tuber-weight than was secured from 8-ounce seed tubers. Possibly there was some inherited tendency in this strain to produce oversize tubers. Probably some oversize tubers resulted here through overweight in seed tubers leading to few eyes per seed piece, few stalks per hill, and few tubers per hill.

(c) Comparisons were made in 1927 of five Green Mountain strains and a substrain, from Vermont, New Hampshire, Maine, and New Brunswick, all but one of which were introduced in the current year. These comparisons generally disclosed smaller differences in yield rate between different strains than between two stocks which originally were parts of one strain. There were greater average differences in yield rate between rows, and between cross-row strips, of the comparison plot, than between strains. Average tuber weight, determined outside the

yield plots, varied, but that might be because there the quarter-tuber seed pieces at planting had also varied in weight with the different shipments or strains. There was no significant difference in tuber dimensions, dimension-ratios, or type.

(d) Comparisons in 1923 and 1924 of different commercial strains of the Irish Cobbler, Spaulding Rose, and Bliss Triumph varieties, gave no apparent difference in plant vigor, or in tuber type as far as measured, after the removal of plants with recognizable diseases.

(2) Comparisons of apparently healthy tuber lines, selected within the same commercial strain, gave results of which the following are the most important.

(a) Of 400 consecutive Green Mountain tuber units, each planted in 4 hills from a 4-ounce tuber, the 40 most productive ones averaged about 80 per cent more in yield rate than the 40 least productive ones. The latter yielded about 5 pounds on the average. The 40 "highs" and 40 "lows" were kept for further comparison. In the next season the difference, though in favor of the high-yielding lines, was only 1.6 per cent. In the third season, following further selection for divergence among these tuber lines, the difference was about 3 per cent, again in favor of the high-yielding lines, and this time with statistical significance. Here the greatest divergence in a pair of matched high- and low-yielding lines was less than differences between rows and cross-strips of similar origin, such differences being attributable to undetected variation in soil and other environmental conditions. Another comparison in the third season gave a slight but significant difference in favor of four high-yielding lines over seven commercial strains. Further tests of three lines during the fourth and fifth seasons gave results mostly opposite in each instance to those to be expected from the name—high- or low-yielding line. The results of this tuber-line selection and comparison did not seem to justify the recommendation of such a process as being practical.

(b) Of the preceding selected 80 tuber lines, as planted in the second year of the comparison, three completely, and two partly, showed "giant-hill" characteristics. These include large vines, yield reduction, later maturity due to frost resistance, and tuber abnormalities, in certain seasons.

(c) Seed tubers of various shapes, in the Spaulding Rose and Green Mountain varieties, did not produce vine types to correspond, or crops with similar shapes to correspond, except in spindle-tuber stock.

(d) Commercial Green Mountain and Irish Cobbler strains which were claimed to be tuber lines, and which probably actually were tuber lines, were not distinctive in yield rate, tuber weight, or tuber type, even when claimed to have been selected originally for superiority in one or another of these characteristics.

(3) Comparisons of the effect of strain with the effects of various other conditions upon yield rate, tuber weight, and tuber type, gave results of which the following are the most important.

(a) With differences expressed in terms of percentage, strain influenced yield rate less than each of several degeneration diseases, less than spraying, less than season, less than fertilizer, within the range of variety, and like location in a field. With regard to influence upon tuber weight, strain ranked below season, below method of planting, below fertilizer, like variety, like selection of overweight seed tubers, like location in the field, and like certain degeneration diseases. With regard to influence upon tuber type, strain ranked below tuber weight, below spindle tuber, somewhat below season within the range of variety, like giant hill, like location in the field, like method of planting, and somewhat above fertilizer.

(b) Two strains, carried along for several seasons, showed a high and significant correlation between the seasonal average tuber weight and yield rate. That is, in any season with greater average tuber weight there was greater yield. This indicates that seasonal yield rate depended upon tuber size more than upon tuber number. There was also a surprisingly high correlation between the yield rate of these two strains and the average yield rate for Aroostook County as reported officially. There was no correlation between yield or tuber weight and the date of the autumnal killing frost.

(c) Considerable change from season to season in tuber weight and W/T (width:thickness) ratio occurred in all strains, with no explanatory differences in the available records on rainfall, temperature, and cloudiness.

(d) Tuber shape was modified differently by potash *vs.* nitrogen and phosphate in commercial fertilizers.

(4) In the course of the various comparisons to which reference has been made, some results were secured as to methods. The most important of these results follow.

(a) Degeneration diseases or viroses can cause changes in hills or in substrains that would give the impression of spontaneous change or of modification by environment (p. 1).

(b) Every apparently healthy commercial strain must be regarded as carrying at least one masked degeneration disease (p. 5, footnote 5).

(c) Comparisons made of commercial strains during the first season after they are brought together from different places, should be regarded as different in value from comparisons made of the same strains after they have been grown together for one or more seasons (p. 5).

(d) During comparisons, the compared stocks should be planted by tuber units and recognizable diseases should be avoided or rogued out (p. 5-6).

(e) In the soil, the natural position of Green Mountain tubers is almost without exception with the broadest surfaces, also called the two faces, facing respectively up and down (p. 6, footnote 6).

(f) Tuber type or shape can be studied quantitatively, and therefore impersonally, to some extent by means of a special caliper, with the securing of dimensions and of dimension-ratios (p. 8).

(g) Tuber shape can be studied also by means of profiles which can be kept as records (p. 8).

(h) Tuber shape or type can be studied effectively by classification according to permanent copies or models of actual tubers (p. 8).

(i) In the same strains, the average width of 8-ounce tubers can be increased by tuber-unit planting (p. 26).

(j) Tuber shape, in any given lot of Green Mountain tubers, changes with an increase in tuber weight (p. 8, 9, 14, 19, 59-62). Thus tuber weight affects appearance through being correlated with shape. Also, uniformity of weight improves appearance regardless of size. Such relationships may explain in

part why extremes are barred by grading rules and trade preference.

(k) There is need for a machine that will sort tubers rapidly by weight (p. 9).

(l) Skips between tuber units can decrease similarity of tuber weight (p. 21).

(m) The average tuber weight can differ, in the same season in the same strain, with cultural differences, being increased by tuber-unit planting with large skips between units (p. 25).

(n) "Ideal" tuber shape as determined by some authorities may not agree with the "standard" shape that represents the majority of tubers grown in the field, even when the weight factor is made uniform (p. 8, 72-73).

(o) Hill yield on the average was 35 ounces with normal competition and 45 ounces with the next hill rogued out, in one set of conditions (p. 17).

(p) Tuber units planted for the origin of tuber lines should be separated by at least 2 missing hills at one-foot intervals (p. 37). With such planting, the roguing of adjacent units can sometimes be done without an effect on yield rate (p. 27).

(q) Cutting 4-ounce tubers into blocky seed pieces can increase the yield in comparison with splitting such tubers lengthwise into seed pieces of the same number but more slender (p. 38).

(5) An analysis of results reported from elsewhere, leads to conclusions of which the following are the most important.

(a) Much care is needed to prove the existence of a real or significant difference as being due to any one factor or condition, either of the current season or of past seasons.

(b) Some tests show that the supposed effects of conditions of the past season on the vigor of the present season's crop, are lacking or at least are not demonstrable. In most of the other tests, such effects of conditions of the past season were due, or might have been due, to differences in infection by perpetuated diseases, especially of the degeneration type (such as mosaic, leafroll, and spindle tuber).

(c) Although bud mutations possibly occur which involve yielding power and tuber type, they have not been demonstrated, and selection of tuber lines has not been proved to be of

benefit outside of effects upon disease and upon the current environment. Tests of the results of selection generally do not have certain advantages possessed by the Aroostook County tests described in this bulletin, with respect to known freedom from certain disturbing diseases and with respect to the use of certain exact, impersonal methods.

(6) As general practical conclusions, the following may be stated.

(a) Commercial strains of the same variety may perhaps actually differ in the same set of conditions, due to inherent differences in nature, with respect to yielding power, tuber weight, and tuber shape. However, if they do differ thus, the fact is very difficult to demonstrate convincingly because of the comparatively great effects of various environmental conditions upon the characteristics mentioned. Further, such differences as may be due to strain are too small to be worth spending time and effort upon them, especially in comparison with differences due to various other conditions.

(b) The preceding applies also to tuber-line or hill-line selections.

(c) Conclusions from strain comparisons are most reliable if applied to the relative values of strains when freshly introduced, unless it is certain that there are no diseases which will spread from one strain to another during a comparison continued for several years.

(d) Practical strain comparisons and tuber-line development require certain careful methods (suggested in the last paragraph of this bulletin).

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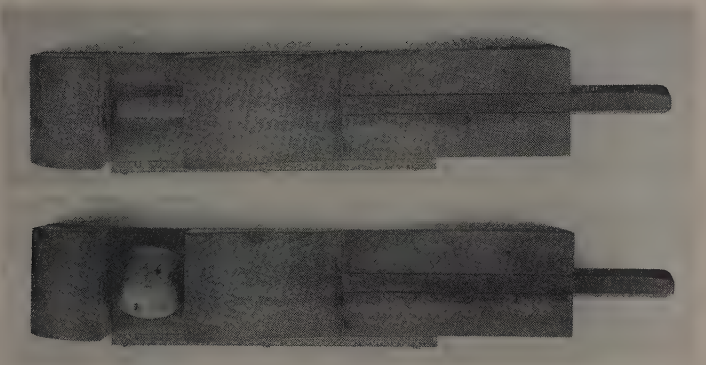


Fig. 16.—Above, wooden caliper, partly open. Below, the same as used for measuring tuber dimensions. Originally devised by Dr. F. A. Krantz of the Minnesota Agricultural Experiment Station.

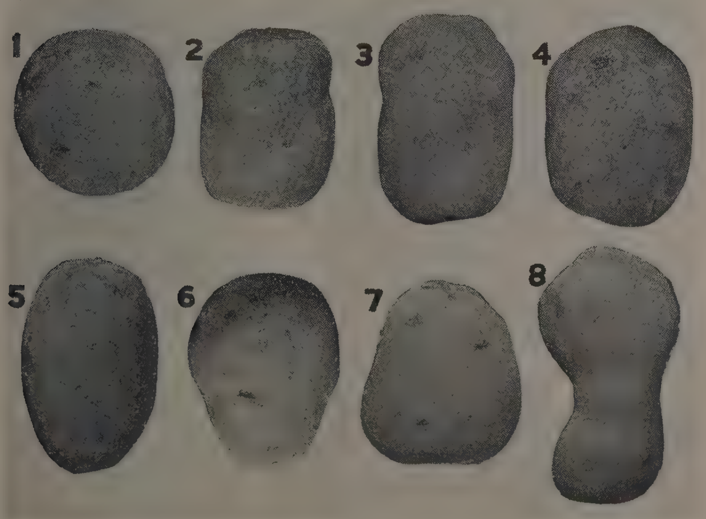
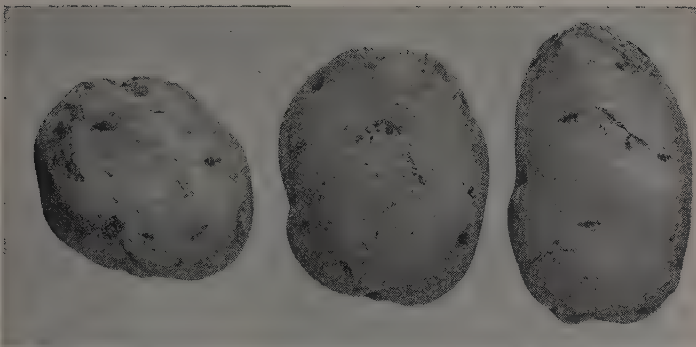


Fig. 17. Eight plaster-of-Paris copies of actual tubers selected as representing eight types of Green Mountains: (1) spherical, (2) short cylindrical, (3) standard, (4) too wide for standard, (5) too long for standard, (6) pointed at rhizome end, (7) pointed at bud end, and (8) wasp-waisted. The L/W (length:width) ratios are respectively 1.03, 1.33, 1.56, 1.38, 1.59, 1.27, 1.16, and 1.82. Although tuber 4 conforms best to the dimensions of the "ideal" type (see text, p. 8 and 72, and Table 10), tuber 3 represented by far the most tubers in the comparison of Green Mountain strains in 1927 (see Table 6).

FIG. 18.—(Above). The twelve 8-ounce tubers coming closest to agreement with the average dimensions of the 8-ounce tubers of the Green Mountain tuber line selected originally for good type. See Fig. 19 for average tubers of bulk stock, see Fig. 7 for profiles, and see Fig. 16 for device for measuring tuber dimensions.

FIG. 19.—(Below). The twelve 8-ounce tubers coming closest to agreement with the average dimensions of the 8-ounce tubers of the bulk Green Mountain stock which was compared in 1928 with a tuber line originally selected for good type. See Fig. 18 for average tubers of the selected tuber line, see Fig. 7 for profiles, and see Fig. 16 for device for measuring tuber dimensions.



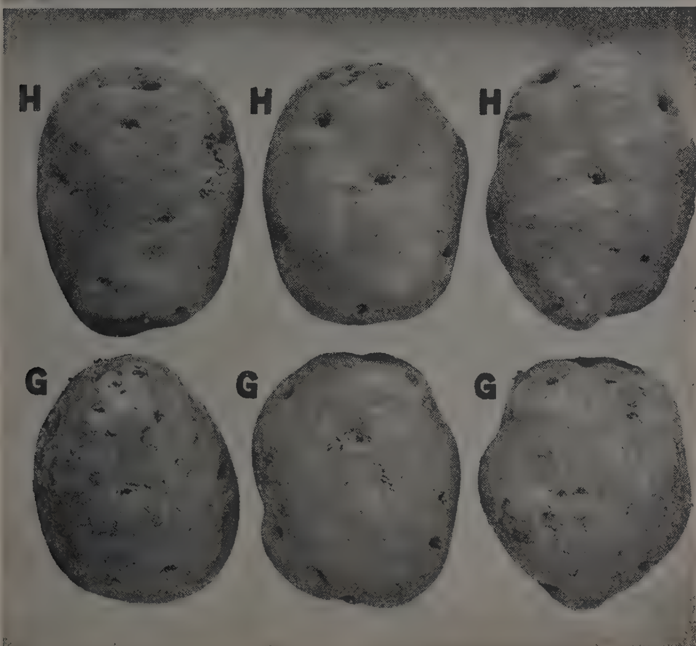


Fig. 20.—(Above). Eight-ounce tubers from Green Mountain giant-hill strain of 1925 comparison. In middle, a tuber close in dimensions to the average which was 9.3×7.4×5.8 cm. or about 3.7×2.9×2.3 inches. The other two are the shortest tuber, 7×8×6 cm. (about 2.8×3.1×2.4 inches), and the longest one, 11×6.5×5 cm. (about 4.3×2.6×2.0 inches). Compare with Figs. 21 and 22.

Fig. 21.—(Below). Eight-ounce tubers from Green Mountain comparisons of 1925. G, from giant-hill strain, representative tubers close in dimensions to the average, including the middle one of Fig. 20. H, from healthy strain, representative tubers close in dimensions to the average, including the middle one of Fig. 22.

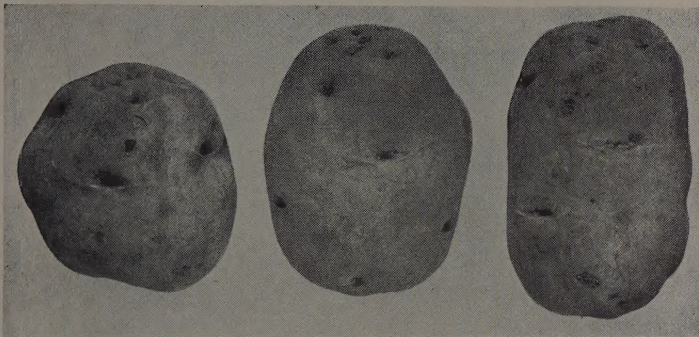


FIG. 22.—(Above). Eight-ounce tubers from Green Mountain healthy strain of 1925 comparison. In middle, a tuber close in dimensions to the average which was 9.5×7.3×5.7 cm., or about 3.7×2.9×2.2 inches. The other two are the shortest tuber, 8×7.5×7 cm. (about 3.1×3.0×2.8 inches), and the longest one, 10.5×6.5×5 cm. (about 4.1×2.6×2.0 inches). Compare with Figs. 20, 21, and 23.

FIG. 23.—(Below). Eight-ounce tubers from Green Mountain spindle-tuber strain of 1925 comparison. In middle, a tuber close in dimensions to the average which was 11.7×6.4×5.5 cm. or about 4.6×2.5×2.2 inches. The other two are the shortest tuber, 9.5×6.5×6 cm. (about 3.7×2.6×2.4 inches), and the longest one, 14.5×6×5 cm. (about 5.5×2.4×2.0 inches). Compare with Figs. 20 and 22.